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PRINCIPLES OF SETTING-OUT SECURING AND TOOLING OPERATIONS

BY THE SAME AUTHOR

MACHINE TOOLS
AND
WORKSHOP PRACTICE

FOR ENGINEERING
STUDENTS AND APPRENTICES

With an Introduction by
WILLIAM ROBINSON
M.E., M.Inst.C.E.

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PRINCIPLES OF SETTING-OUT

SECURING AND TOOLING OPERATIONS

FOR ENGINEERING STUDENTS AND APPRENTICES
AND STUDENTS IN MANUAL TRAINING
—METAL WORK

BY
ALFRED PARR
FIRST HONOURS SILVER MEDALLIST METAL WORKING TOOLS, CITY AND GUILDS
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WORKSHOP PRACTICE, UNIVERSITY COLLEGE, NOTTINGHAM
AUTHOR OF "MACHINE TOOLS AND WORKSHOP PRACTICE"

WITH AN INTRODUCTION BY
C. H. BULLEID, M.A., A.M.I.C.E.
PROFESSOR OF ENGINEERING, UNIVERSITY COLLEGE, NOTTINGHAM

WITH 250 ILLUSTRATIONS

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INTRODUCTION

THE ever-increasing variety of engineering work, and the degree to which specialisation is carried in modern manufacturing processes, renders it more and more difficult for a workman to obtain a full knowledge of his trade, and to no branch of work does this apply more than to Setting-Out. A man trained in a type-writer factory may acquire a sound knowledge of jig and templet work and die-making, but have very little experience of dealing with castings and forgings of any size on a marking-off table, whereas, a man working in a general repair shop has plenty of work of the latter kind and very little of the former. Moreover, there is an increasing tendency for Setting-Out to become a separate department, the man who machines an article working to instructions received from the tool room or gauge department. This being so, the need for classes in Setting-Out is manifest, and this book has arisen out of the Lectures and Workshop Practice instruction given by Mr. Parr at University College, Nottingham.

At one time Setting-Out meant covering a casting or forging with whitewash and drawing in the lines with a scribing block on a table, now it involves in addition the use of special fixtures for holding the work on the machines, jigs for drilling through, and templets and gauges for setting the tools and testing the accuracy of the work, many articles being finished without a single line being drawn on them. The man who sets out work must be well acquainted with the construction and use of such appliances, and with the proper tolerances and allowances for various classes of fits, as well as with the best methods of holding work and the proper cutting speeds. No apology is therefore needed for the inclusion of such information in a book on Setting-Out.

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Professor of Engineering.

UNIVERSITY COLLEGE,
NOTTINGHAM.

PREFACE

In compiling the contents of this book the Author has endeavoured to select examples from some of the best engineering workshops to illustrate the stages and processes through which the work passes. He has been guided by his experience to treat the subject in such a way that an intelligent beginner should not find it difficult to grasp the principles of Setting-Out work, properly locating it at the various machine tools, and of selecting suitable cutting tools for finishing it to the desired form and dimensions. The improved method of working to precision gauges, and the universal adoption of drilling, milling, and planing jigs, have rendered it practicable for all pieces of any mechanism of whatever magnitude to be made alike in detail; hence we may have a universal system of manufacturing machines with every part interchangeable. The assembling and gauging departments have become most important, whilst the instruments in daily use to verify the accuracy of construction are remarkable examples of precision. These instruments are shown at the beginning for the general student, but for the more advanced student the use of the same instruments are frequently seen in testing the accuracy of pieces of work, throughout the book.

Jigs have been well considered, and examples of drilling, milling, and planing taken to illustrate their respective uses.

The rapid progress of the grinding wheel and the modern high-speed steel cutting tools have been duly noted; while considerable space has been devoted to gears and gear cutting, including the generating system.

The Johansson gauges are the outcome of precision grinding processes; whilst the new electric measuring machine by Dr. P. E. Shaw, will hold a gauge and align it accurately in any desired position for the gauge to be tested. With this machine it is now possible to show small inequalities even in the Johansson gauges. This machine is now installed at the National Physical Laboratory, Teddington.

The Author again wishes to thank the engineers and firms referred to whose names appear in the text or on the engravings of the machines of which they have kindly supplied photographs or drawings. Also to Harold B. Lawson, Esq., B.Sc., and H. H. Pike, Esq., for valuable assistance in making the drawings from the Author's rough sketches.

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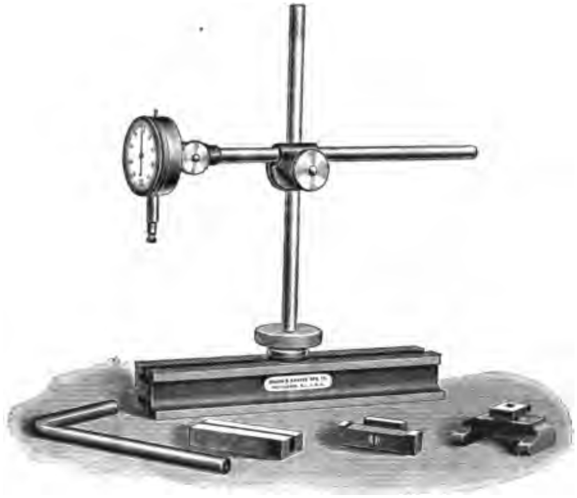

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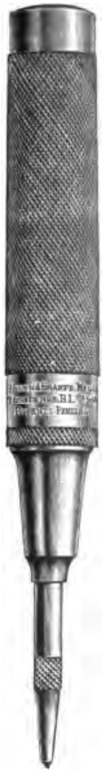

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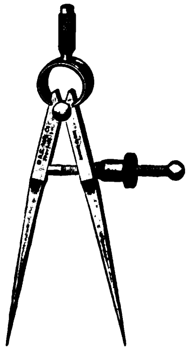

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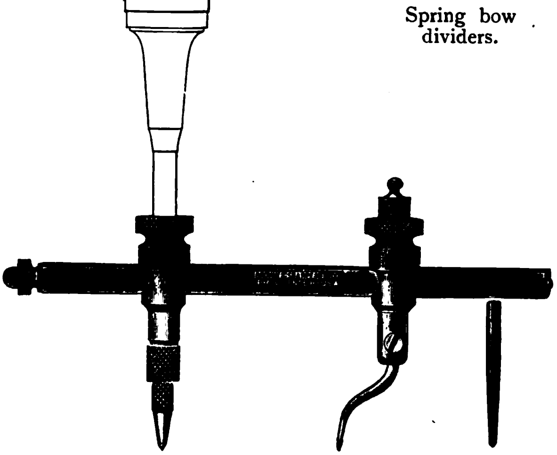

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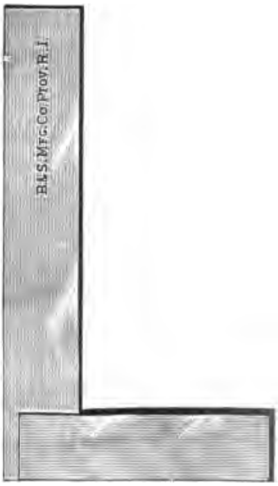
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THE
PRINCIPLES OF SETTING-OUT

SECURING AND TOOLING OPERATIONS

THE present system of working in many of the large engineering works renders it almost impossible for all young engineers to get instruction in the principles of setting-out work. An apprentice here and there may be fortunate enough to be placed for a time at the table with the man in charge, but where premiums are not paid there is no recognised obligation on the part of the management to push forward the youths and to see that they are taught the underlying principles which govern all good work.

Since there are comparatively so few who get the opportunity of preparing the work for the various stages of machining, it is not surprising to find a general lack of intelligence on the principles of "Projection of Plans," "Elevations," "End," and "Sectional" views of the various parts of engines and of machines. The general practice, therefore, is to select an intelligent workman who can accurately read the drawings, and who can be relied upon to correctly copy from them the various shapes and dimensions of the objects they represent, and to transfer these particulars to the work in hand.

Such workmen have usually had instruction at evening classes in the subjects of Machine Construction and Drawing, and of practical, plane, and solid geometry, and generally it will be found that in addition they have had considerable practice in drawing at home. It may be that the division of labour has prevented many young engineers from seeing work done, as well as preventing them from doing some things by hand themselves which are now done by automatic machines. Thus they are less acquainted with the methods formerly adopted. It will therefore be the aim of the writer to attempt in a plain and simple manner to select some parts of engine and of machine construction, and to show how they may be "set-out," "secured," and "tooled" at the various machines.

Examples will be taken showing the different ways of doing the work, as is the case when one object only is required, several, or large quantities of the same kind.

The Principles of Setting-out.—Setting-out may be divided into two parts, viz.: the first setting-out directly from the castings and forgings as they are sent from the foundry, forge, and smithy respectively; and the second part where marking-out has to be done after certain tooling operations have been performed. Generally, those iron castings which form parts in the construction of engines and machines are marked out from a rough base, such as engine beds, machine bodies, and standards, which are finally to stand on the ground level or are grouted in a bed of cement. It is therefore imperative to have a base plate or surface plate of the evenness and truth of which there can be no possible doubt whatever. For convenience these plates are called "Marking-out" or "Lining-out" tables, and may be used quite level with the shop floor line when large work has to be set out, or the plate may be elevated on a suitable body standard for work of smaller proportions.

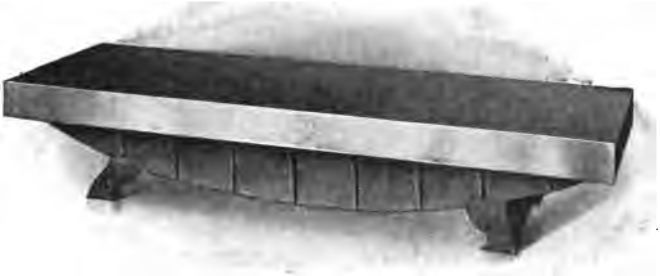

FIG. 1.—Lining-out table.

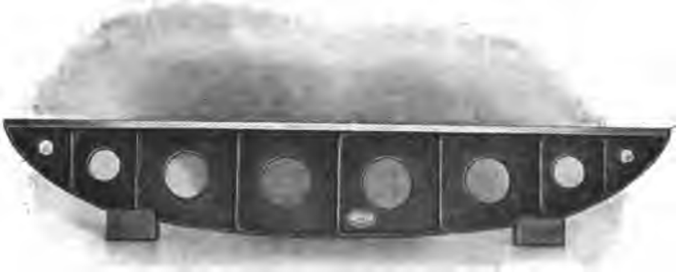

FIG. 2.—Cast-iron straight-edge.

To prevent any possible deflection, the plates are made with stout ribs at close intervals beneath the surface (see Fig. 1). The sizes vary considerably and may be from 3 ft. to 12 ft. square. The edges are at right angles to the surface and to each other. Some tables are provided with finely scribed lines at equal distances apart, and these are crossed by another series of lines running at right angles to the first. These lines are very convenient when setting pieces of work which have more than one surface to be considered. Measurement may be quickly taken from the lines and transferred to the object.

The tools and appliances which are used at the table must be accurately made, as, obviously, any small errors will soon be multiplied if the lining-out tools are faulty. Among these there will be various sized pairs of Vee blocks and of parallel blocks to support the work, large and small surface gauges, long and short straight-edges (Fig. 2), and squares, steel rules of various lengths and readings, large and small compasses, trammels, various calipers (outside and inside), odd legs, hand scriber, bevel square, centre punches, wedges of wood and of iron, etc.

Generally the castings and forgings are pickled in dilute sulphuric acid to remove the scale, and the surfaces to be tooled are placed in a horizontal position.

STRAIGHT-EDGES

Straight-edges are frequently used to align surfaces which are intended to be flat. In engine and machine construction and in erection of the various parts, straight-edges are in frequent use. They are used in conjunction with measuring rods and other fixed or movable gauging instruments, and in testing work during the machining and other finishing stages. As the name implies, it is essential that the strip of metal should be reliably straight from end to end, however long the straight-edge may be. Therefore it is imperative to carefully use them, and to place them when not in immediate use in a suitable position away from all possibility of injury. For this reason they are sometimes kept in the tool room or in the care of the foreman or other responsible person. Straight-edges may be produced correctly in two ways. The first is to machine up the steel strip, making one edge thin; and finally finish by draw filing and scraping to a true plate—a surface plate.

Some of the short straight-edges are bevelled on both sides to a feather edge, and then finished by hand. Made in this form, small local elevations on a piece of work may more easily be located than is the case when the edge is made rectangular.

In some cases the edge is $\frac{1}{16}$ in. broad, and in the others made to a "knife edge," by bevelling off one or both sides.

The second method is adopted in the absence of a surface plate long enough on which to make the necessary tests, or where there is not a long straight-edge to hand. The method of procedure is similar to the one of originating a true plane. That is where three straight-edges must be made together by the "Whitworth" system of interchanging. Obviously, if two only were made, they could agree when otherwise than straight. This, however, could not be so if three straight-edges were made and worked together.

Numbering them 1, 2, and 3 respectively, we may work Nos. 1 and 2 together, and Nos. 3 and 1, and similarly Nos. 2 and 3 may be tested. The plan of finishing is to hold the edges together until no light can be seen at any point. The dressing may be done by grinding or lapping. No. 1 may be regarded as a master, and Nos. 2 and 3 tested and both corrected to it; on assembling Nos. 2 and 3 together, any defect on the edge of No. 1 will be at once visible, because it will be double the actual amount of error on the edge of No. 1. We may now give very careful attention to No. 1 and correct it. Nos. 2 and 3 must be similarly treated and compared separately with No. 1, and again Nos. 2 and 3 together. The process must be carefully repeated until all three edges agree—whichever pair are brought in contact. Very light and thin straight-edges may be hardened throughout by heating and quickly quenching the edge. The best results are obtained by immersing the whole surface at once, *i.e.* the edge from end to end should strike the water at the same instant. The longer ones should be clamped between two plates, and the whole uniformly heated. Secured in this way the tendency for the steel to buckle or warp is obviated. It should also be stated that, by having a small amount of the metal back of the edge projecting outside the clips, that portion is made quite hard, while the part trapped by the plates, being longer in cooling, is only partially hardened, or, if desired, may be cooled so gradually as to remain soft.

Hints on "Marking Off"

In the first place, the casting or forging should be overhauled to ascertain whether the job will "clean up" all over, before commencing to line out any part whatsoever.

Having considered this, the next thing is to strike as many lines as possible with the same setting of the scribing block, also to strike all lines possible, without moving the work to a second position.

Due care must also be given to the way the job is to be set up, by the workman at the machine making his task as simple but as clear as possible by working to the lines given. The dimensions must be very carefully noted and applied to the work. The lines must be thin but definite, and the marker off should be familiar with the sequence of operations. As an example, a flange may require to be machined for drilling bolt holes, etc.; such a flange, however, may be still in the rough; therefore to mark out the holes for drilling at this stage would be a mistake, because the lines would be tooled out in facing up. It will therefore be clear that the marker off must be aware of the workshop methods of handling each piece of work, and know exactly how much tooling will be done at the first setting out, and the next or subsequent settings, so that no useless marking off will be done.

When the marking off has to be done through a sheet templet, there should be lines on it, to be used when locating the true position. Generally the work has a machined face, from which measurements may be taken; such, however, not being the case, either horizontal or vertical lines on the templet materially assist in putting it in place on the work. It is much the safest plan to attach the templet to a face already tooled, this point is well illustrated in Figs. 41, page 29, in "Machine Tools and Workshop Practice," marking off the bed of a shaping machine.

Our next example, Fig. 3, is a rectangular bar of mild steel 1 in. by ½ in. by 4½ in. It is intended to represent a slotted link, the slot to be made in the centre of the bar and to be 2½ in. long by ½ in. wide. Assuming that the bar is to be filed up, this can be done with a second cut file, and gauged for dimensions by the use of a sliding caliper gauge. When satisfactorily parallel and flat, it is placed on its edge on the marking-out table, chalked over and a line AB drawn through the centre, as shown in Fig. 3. The bar is then turned to stand vertical and an intersecting line scribed through the centre at CD. The bar can now be fixed in the vice, then with a pair of compasses, with the points set at ¼ in. apart, 5 circles can be described on line AB, using the centre line CD as the centre of the first circle described. To facilitate the marking-out a fine centre dot should be punched where CD intersects the line AB. Then, with this point as centre, describe and dot this circle on the four points of intersection. Two other circles on each side should be similarly described and punched, and the work is ready for drilling.

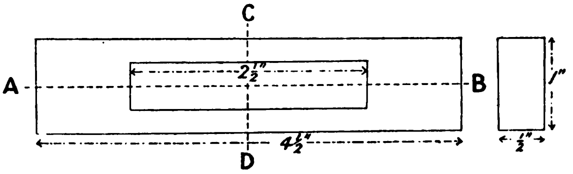

FIG. 3.—Slotted link.

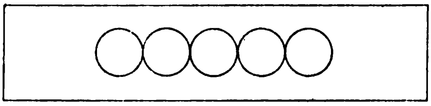

FIG. 4.

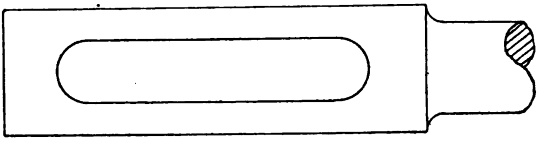

FIG. 5.—Finished slot with rounded ends.

To assist the drill point in starting truly, the centre of each circle should be punched deeper. Sometimes, however, the drill will wander. This can generally be arrested by chipping with a narrow round-nosed chisel a shallow groove from the edge of the hole to the centre. This new centre alters the path of the drill and the process is repeated until the path of the drill is concentric with the circle described. To assist beginners, a smaller circle is described so that any error may be detected more definitely.

It may be taken as a general principle that during the process of tooling, the work should be firmly secured to the machine table. In the above example of drilling, the work would be held in a parallel machine vice or supported on two parallel strips and secured to the drilling-machine table.

The only exceptions to the above rule are where the work is large and the hole to be drilled very small, then of course the work would be as stationary as when fixed by bolts. There is another admissible case, for example, in drilling small holes through thin metal strips. Here the metal bar could he held by the left hand, while the drill is fed by the right.

Were this allowed in drilling a bar $\frac{1}{2}$ in. thick with a drill say $\frac{1}{2}$ in. or $\frac{3}{4}$ in. diameter, the position of the hole when finished would not be true to its marking, neither would it be at right angles to the upper surface.

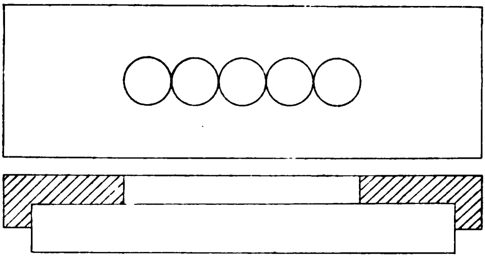

FIG. 6.—Jig for drilling slotted link.

In direct contrast is the fact that where it is necessary to be particular as to the precise position and truth in finish of the holes, the work is placed beneath a jig or drill guide reliably made, and the two firmly secured to the machine table (Figs. 6, 7).

This method of drilling is most important for interchangeable parts, and will again be referred to.

When drilling the five holes in the bar shown in Figs. 3 and 4 the size of the drill will be $\frac{1}{64}$ in. or $\frac{1}{32}$ in. less than the finished width of the slot, this small amount being left for filing and finishing after the holes have been chipped out. Before any chipping is done two definite lines should be scribed on each face, indicating the actual

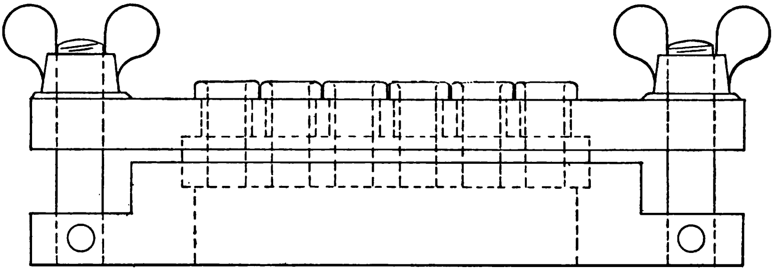

FIG. 7.—Bushed drilling jig.

width to which the slot is to be made. Then, while the work is resting evenly on a chipping or bench block, the cutting out of the slot can be commenced by using a thin flat chisel having a keen edge. Now, there is a danger of breaking the chisel by keeping it too much in a groove *i.e.* by hammering until the sides of the chisel act as a wedge. To avoid this, great care must be exercised in placing the chisel just within the line on each side of the work, and then, by alternating the face of the work uppermost, each side of the work will get the same amount of treatment, removing the chips as fast as they are made, or they will get beneath the surface. The slot will appear somewhat bevelled towards the centre from each face of the bar.

The piece is next gripped in the vice to the line, and by very light blows the chisel is made to cut out the slot, leaving the face fairly flat and smooth. This, however, will be improved by rubbing the end of the chisel in oily waste, making it glide easier and certainly helping it to keep its cut and thereby produce a level surface.

The chisel must be held at an angle to the vice jaws, so that there will be no breaking of the edge of the slot, which might happen if held at right angles to the face of the work.

An example of a link with rounded ends is given in Fig. 5, the ends being finished without disturbing the true radial curves as left by the drilling. The same link is shown in Fig. 8, being gauged and tested for size and truth with inside and outside calipers. The leading of the flat surface into the curves has to be done with great care. For work of this character half-round files of various grades are used: the truth and progress of the filing should be noted, so that there will be just enough metal to be finished by draw filing, *i.e.* moving the file longitudinally in the slot while holding it evenly with both hands. The short files are much more easily balanced than long ones, indeed it is a task for an expert to balance a 12-in. file while using it on a bar ½ in. thick by holding each end. Round files are usually coarse and are the most difficult to guide. Were we to use a round file in the slot we should find the surface of the hole most irregular, and larger at the extremities than the required dimensions. Therefore, these files should only be used to enlarge rough holes, the actual truth and finish of which are in no way particular.

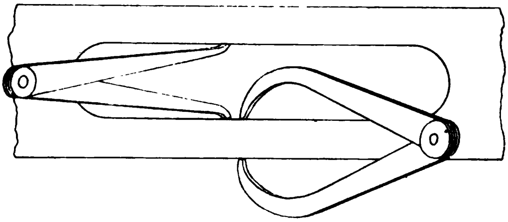

FIG. 8.—Testing link with calipers.

The simple guide plate or jig (Fig. 6) secured above the surface of the work, and through which the drill passes, ensures the true position of the holes without the trouble of setting-out. A more positive arrangement is to bush the jig plate as shown in Fig. 7. This, however, is used to locate holes precisely spaced, and will be hereafter referred to under the head of "Jigs."

There are methods whereby slots of this description can be cut out entirely by a machining process. The tool rotates similarly to a drill, but the table carrying the work is traversed the full length of the slot and back again. In this case the tool is automatically fed through the bar. Another plan is to use two tools, one operating from each side of the bar, leaving a thin fin to be removed by hand tools; by this arrangement more work can be done, since each tool cuts only halfway.

MEASUREMENT AND MEASURING INSTRUMENTS

The Imperial standard yard is the distance between the centres of two fine lines engraved on two gold plugs let in a bronze bar. At 62° Fahr. the precise distance is 36 in.

From this unit of length all measurement has been ascertained. Measurement is of two kinds—End and Line.

End measurement implies that a precise dimension has been obtained, and then transferred to a given object or instrument. The object may be a metal rod the length of which is just 3 in., or a cylindrical plug the diameter of which is precisely 3 in. Line measurement means the approximate measurement which may be obtained by the use of a wood or steel rule, such as the dimensions of a board or the length of an iron bar. A rule will also satisfactorily show us the width and diameter of a pulley; it may further show that the bore is about 2 in. diameter; it will not, however, accurately indicate that the pulley will be a sliding or a driving fit on a 2-in. diameter shaft. This very precise measurement is not to be ascertained by sight, but by "feeling," *i.e.* by the sense of "touch." Reference must therefore be made to a reliable standard gauge of 2 in. diameter (Fig. 9). The dimensions must be carefully copied and transferred. It is then by comparison that we actually decide when parts are correctly adapted to fit each other. There are many forms of gauges, but all bear definite relation to the above standard yard. In particular we have

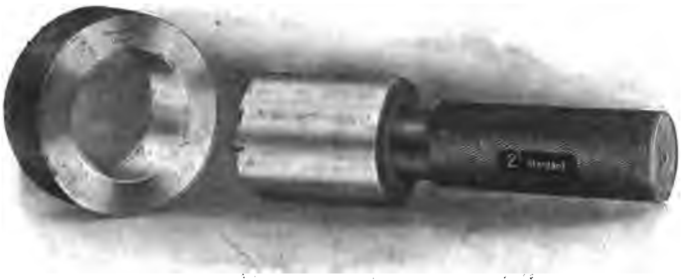

FIG. 9.—Cylindrical standard gauges 2 in. diameter.

cylindrical plug and ring gauges, end measuring rods, reference discs, "limit" gauges, micrometers, verniers, sliding calipers, fixed caliper gauges and screw gauges; also the Johanson system of gauges, which will be fully explained later. All these are now in request in the various stages of engine and machine construction. By their means complex mechanisms may be built in various parts of the country, and, when assembled, will need no subsequent correction. It is possible for a skilled workman to obtain and transfer measurement with ordinary movable calipers, and do excellent work. It is, however, not possible, using such gauges, to make the work interchangeable.

This interchangeable system admits of no subsequent correction, and it therefore follows that the work during the tooling and finishing stages must be correct in every detail. To accomplish this end it has become imperative to make each piece of work accurate within limits. Therefore the system of limit gauges has been adopted. The gauges are carefully ground, and have the limit of error allowable stamped upon them. It is impossible in a general engineering workshop to make each piece of work fit the internal or external standard gauge satisfactorily alike, as there are so many kinds of fits required that it would be impossible to leave the decision to the workman's independent judgment.

It has been found that a "highly polished spindle will enter a ring gauge with a variation of −0·0002 in., and a plug gauge will enter a smoothly finished hole with a variation of +0·0002 in. This, however, is not sufficient allowance for lubrication if the spindle has to revolve, consequently it is left to the judgment of the workmen as to the ease with which the gauges should fit the work." From the foregoing it will be understood that a limit gauge system can be easily adopted for every class of work whatsoever, and the operatives who work daily with these gauges produce the most uniform work in a minimum time.

Limit gauges are usually double-ended (see Figs. 10 and 11), one end being larger and the other smaller than the standard size. They are usually stamped, "Go on," and "Not go on," and when used properly the gauge will pass over the work at one end, and not at the other. The gauges are manufactured in the following kinds: Running

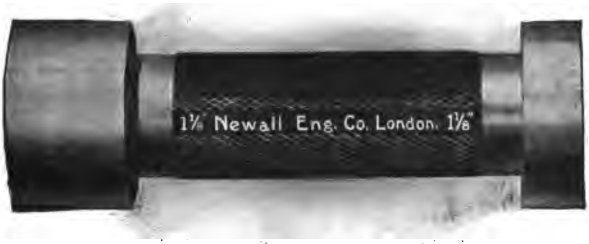

FIG. 10.—Limit gauge.

fits, force fits, driving fits, and push fits. The amount of allowance for these various fits is shown in the table appended.

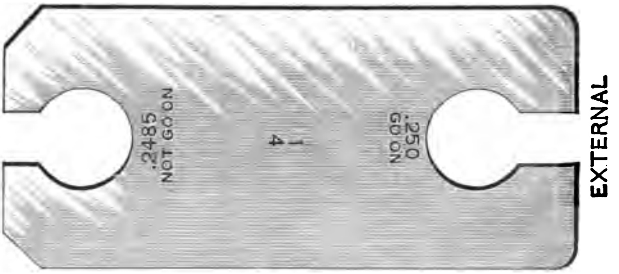

FIG. 11.—Limit gauge.

TOLERANCES IN STANDARD HOLES.

(2 *Grades.*)

	Nominal diameters.	Up to ½″	9/16″–1″	1 1/16″–2″	2 1/16″–3″	3 1/16″–4″	4 1/16″–5″	5 1/16″–6″
Class A.	High limit	+·00025	+·00050	+·00075	+·00100	+·00100	+·00100	+·00150
	Low ,,	−·00025	−·00025	−·00025	−·00050	−·00050	−·00050	−·00050
	Tolerance	·00050	·00075	·00100	·00150	·00150	·00150	·00200
Class B.	High limit	+·00050	+·00075	+·00100	+·00125	+·00150	+·00175	+·00200
	Low ,,	−·00050	−·00050	−·00050	−·00075	−·00075	−·00075	−·00100
	Tolerance	·00100	·00125	·00150	·00200	·00225	·00250	·00300

ALLOWANCES FOR VARIOUS FITS.

Force Fits.

	Nominal diameters.	Up to ½″	9/16″–1″	1 1/16″–2″	2 1/16″–3″	3 1/16″–4″	4 1/16″–5″	5 1/16″–6″
Class F.	High limit	+·00100	+·00200	+·00400	+·00600	+·00800	+·01000	+·01200
	Low ,,	+·00050	+·00150	+·00300	+·00450	+·00600	+·00800	+·01000
	Tolerance	·00050	·00050	·00100	·00150	·00200	·00200	·00200

Driving Fits.

	Nominal diameters.	Up to ½″	9/16″–1″	1 1/16″–2″	2 1/16″–3″	3 1/16″–4″	4 1/16″–5″	5 1/16″–6″
Class D.	High limit	+·00050	+·00100	+·00150	+·00250	+·00300	+·00350	+·00400
	Low ,,	+·00025	+·00075	+·00100	+·00150	+·00200	+·00250	+·00300
	Tolerance	·00025	·00025	·00050	·00100	·00100	·00100	·00100

Push Fits.

	Nominal diameters.	Up to $\frac{1}{2}$″	$\frac{9}{16}$″–1″	$1\frac{1}{16}$″–2″	$2\frac{1}{16}$″–3″	$3\frac{1}{16}$″–4″	$4\frac{1}{16}$″–5″	$5\frac{1}{16}$″–6″
Class P.	High limit	−·00025	−·00025	−·00025	−·0005	−·0005	−·0005	−·0005
	Low ,,	−·00075	−·00075	−·00075	−·0010	−·0010	−·0010	−·0010
	Tolerance	·0005	·0005	·0005	·0005	·0005	·0005	·0005

Running Fits (3 *Grades*).

	Nominal diameters.	Up to $\frac{1}{2}$″	$\frac{9}{16}$″–1″	$1\frac{1}{16}$″–2″	$2\frac{1}{16}$″–3″	$3\frac{1}{16}$″–4″	$4\frac{1}{16}$″–5″	$5\frac{1}{16}$″–6″
Class X.	High limit	−·00100	−·00125	−·00175	−·00200	−·00250	−·00300	−·00350
	Low ,,	−·00200	−·00275	−·00350	−·00425	−·00500	−·00575	−·00650
	Tolerance	·00100	·00150	·00175	·00225	·00250	·00275	·00300
Class Y.	High limit	−·00075	−·00100	−·00125	−·00150	−·00200	−·00225	−·00250
	Low ,,	−·00125	−·00200	−·00250	−·00300	−·00350	−·00400	−·00450
	Tolerance	·00050	·00100	·00125	·00150	·00150	·00175	·00200
Class Z.	High limit	−·00050	−·00075	−·00075	−·00100	−·00100	−·00125	−·00125
	Low ,,	−·00075	−·00125	−·00150	−·00200	−·00225	−·00250	−·00275
	Tolerance	·00025	·00050	·00075	·00100	·00125	·00125	·00150

Referring to the various classes of fits, it has been found to be advisable to have some gauges adjustable, such as is illustrated in Fig. 12. These gauges may be set to reference bars, which are ground

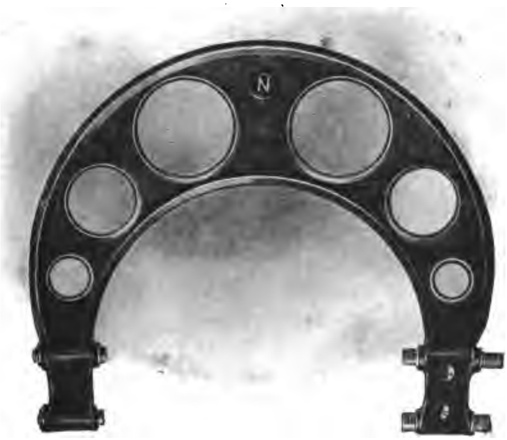

FIG. 12.—Adjustable micrometer gauge.

to exceedingly fine limits. The smaller sizes have a range of $\frac{1}{4}$ in. to $\frac{1}{2}$ in. up to 12 in. Above this the range is 1 in. up to 60 in. They are also used for testing when "roughing out" work, and by adjustment can be used for finishing. A reference bar is shown in Fig. 13. These are used in accordance with the table given, and are marked "high and low," and are within an error of 0·0002 in. Similarly, there are standard reference bars (Fig. 14). These are also serviceable when setting the adjustable external limit gauges precisely to standard sizes along with the setting dials, shown in Figs. 15 and 15A. After the external limit gauges have been set to the gauge, the screws are locked, and the dial and index inserted in the holes of the screws at zero.

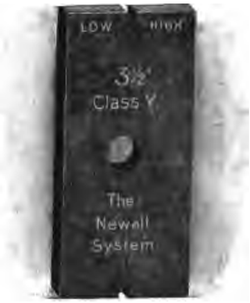

FIG. 13.—High and low standard gauge.

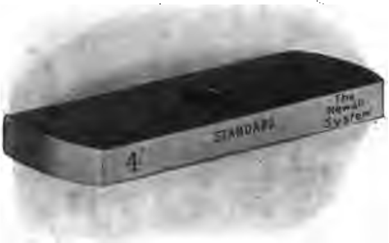

FIG. 14.—4-in. standard bar.

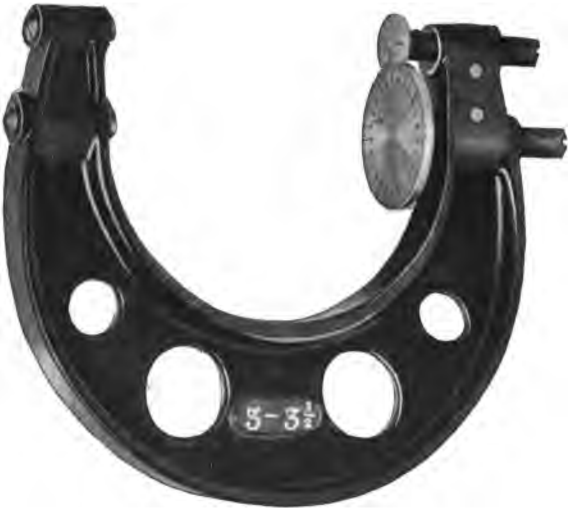

FIG. 15.—Adjustable micrometer gauge.

The screw carrying the dial is released and can be adjusted to the required allowance, either above or below standard, by rotating the screw in the plus or minus direction, as shown by the arrows on the index. This screw should then be locked, the dial and index transposed, and the process repeated with the other screw. The dials are divided into thousandths and subdivided into $\frac{1}{4}$-thousandths.

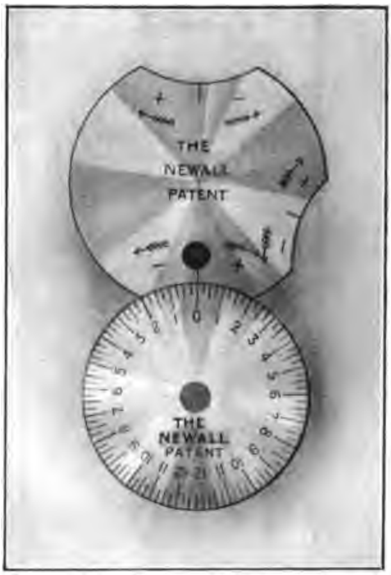

FIG. 15A.—Enlarged view of dials.

A very useful form of screw gauge is shown in Fig. 16, both for internal and external screw threads. On the end of the internal gauge a plug is turned giving the external diameter of the screw at the bottom of the thread; the external gauge is adjustable.

Twist drill shanks are turned to the Morse taper, but the sockets are sometimes left parallel, so that they may be adapted to suit any form of drill socket; therefore a standard taper gauge is necessary. It is not convenient to fit the parts until the flat is made, but by using a pair of gauges similar to Fig. 17 the flat portion need not now be considered.

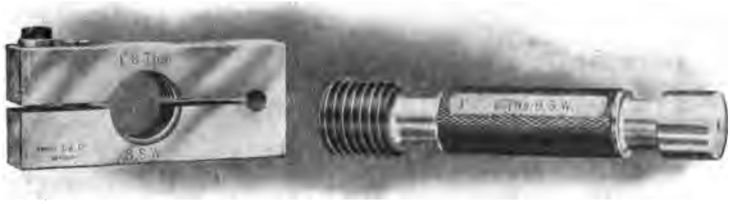

FIG. 16.—Internal and external screw-thread gauges.

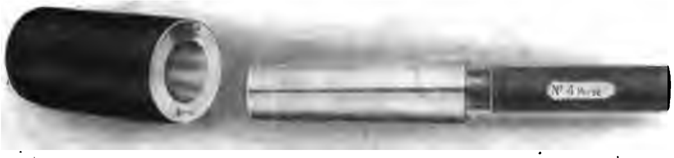

FIG. 17.—Standard taper gauges.

Measuring Machines

Measuring machines are in more frequent use since the adoption of the interchangeable system of manufacture. To maintain a high degree of efficiency in the various tools, and in instruments of precision, gauges, etc., in the tool room, measuring machines are imperative. Fig. 18 illustrates a comparatively new form of machine; the feed screw has 20 threads per inch, and is of buttress form. To keep the wear uniform, the screw and the nut are alike in length. It will be seen that the tailstock carries a microscope for setting to the rule and the anvil operating the indicator. A novel feature in this machine is the spirit-level indicator. Pressure applied to the anvil through the piece being measured tilts the spirit-level, and owing to the curvature of its vial the movement of the bubble magnifies that of the anvil about 4000 times. This form of indicator reveals any minute expansion or contraction of the piece being measured, due to varying temperature, and the makers contend that it is more sensitive than the "feeler" system. When a number of pieces of the same approximate size are to be compared in the machine, the fine adjustment arm can be reversed and the back horizontal bar used as a stop; differences in the size of the pieces are then shown on the indicator.

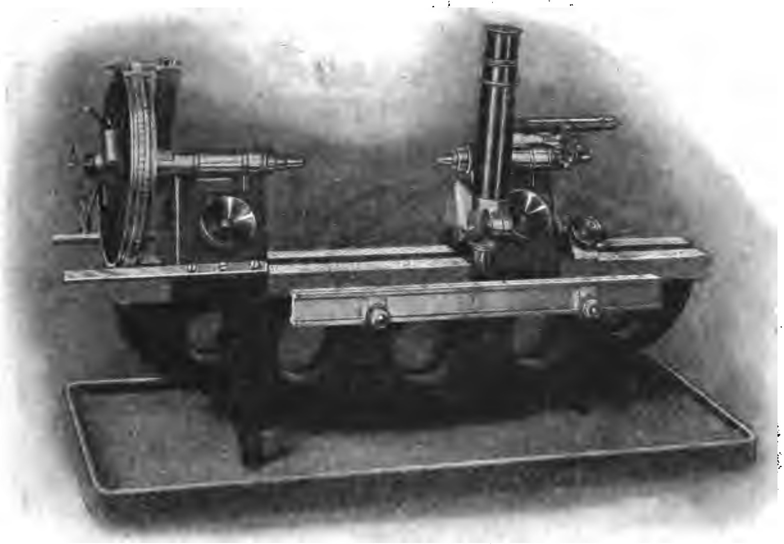

FIG. 18.—Precision measuring machine.

The machine has a capacity to give readings to one 100,000th part of an inch, the graduations on the wheel being arranged so that the size indicated can be read in decimals of an inch. Fig. 19 shows a reading of 0·31254; the first digit, 3, is the highest figure disclosed on the scale carrying the vernier; the second and third digits, 1 and 2, will be shown as the highest main graduations; and the fourth digit, 5, the highest subdivision on the measuring wheel in front of zero; and the fifth digit, 4, will be that graduation on the vernier which is in line with any graduation on the wheel.

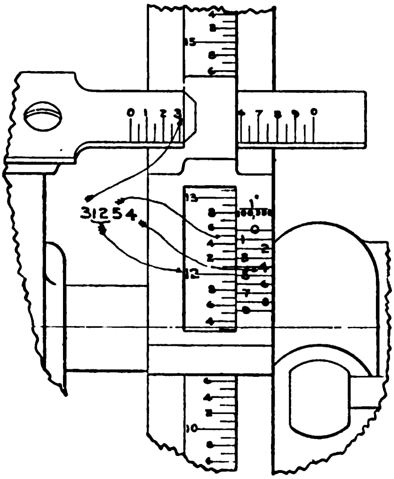

FIG. 19.—Vernier.

A separate view of the measuring wheel and the fine adjustment arm is given in Fig. 20.

When comparing a number of pieces of the same approximate size, the fine adjustment arm can be reversed, and the back horizontal bar used as a stop; differences in the size of the pieces will be shown on the indicator.

This machine, therefore, will indicate that a standard size has or has not been obtained by its comparison with a known standard. A standard of length may be placed between the feelers, and precise readings taken; then, when a copy has been attempted and a trial of its dimensions taken in the machine, indications will at once show when the copy is like the original, or whether it is larger or less than the original, and the amount of error in either direction will be read to the one 100,000th of an inch, if so precise a measurement is desired.

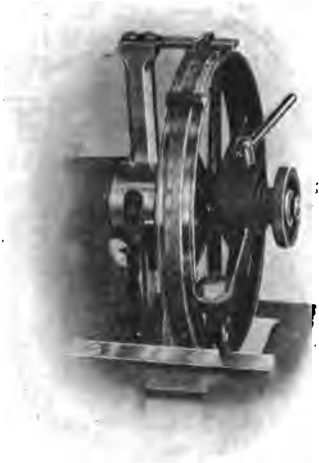

FIG. 20.—Enlarged view of measuring wheel.

A measuring machine of a high degree of precision has been perfected by Dr. P. E. Shaw. This machine is unlike other machines which are actuated by purely mechanical manipulations.

Johansson System of Gauges

The Johansson system of gauges is the assembling of a series of hardened, and truly ground, flat steel plates of varying thicknesses.

The first set of the four series is divided as follows: 0·1001 to 0·1009 by 0·0001 in.

The second set of the series from 0·101 to 0·149 by 0·001 in.

The third set of the series from 0·050 to 0·950 by 0·05 in.

The fourth set of the series of four pieces, which have lengths of 1, 2, 3, and 4 in. respectively.

It will thus be seen that the blocks in the first series will divide up the spaces between those of the second series, while the third and fourth series can be divided up by the first and second series. Thus any size can be obtained from 0·2000 in. up to 8 or 10 in., rising by 0·0001 in.

In addition, it is possible to get the same size or combination in several ways, *i.e.* taking, for instance, 2·3769 in., which can be obtained as follows:—

A	B	C
0·1009 in.	0·1001 in.	0·1002 in.
0·126 ,,	0·1008 ,,	0·1007 ,,
0·150 ,,	0·106 ,,	0·116 ,,
2·000 ,,	0·950 ,,	0·110 ,,
	0·120 ,,	0·250 ,,
	1·000 ,,	0·800 ,,
		0·900 ,,
2·3769 ,,	2·3769 ,,	2·3769 ,,

The above combination of gauges when actually built up is only to be obtained by carefully noting the following: 1. The measuring surface should be absolutely plain, in order to admit the close approach of two gauges to each other when assembled. 2. The two measuring surfaces of one gauge should be absolutely parallel with each other, so that the end surfaces of a combination of a number of gauges remain equally parallel. 3. The degree of accuracy of each single gauge should represent the highest possible accuracy, so that the accuracy of any combination would be held or maintained, which is necessary for checking purposes. 4. The accuracy of the single gauges should be proportionate to the nominal length of the gauge, that is, the smaller the gauge is the higher should be the accuracy, so that a combination of a number of gauges has the same accuracy as a single gauge of a corresponding length, or in other words, the combined gauge and the single gauge of the same length should have the same degree of accuracy. (In Fig. 21.)

The combination gauge and a similar size gauge are wrung to the surface of another gauge, on the opposite side a further gauge is wrung, thus proving the statement given in paragraph 4. By combining a set of gauges similar to those shown in Fig. 22 a "Snap" and "Plug"

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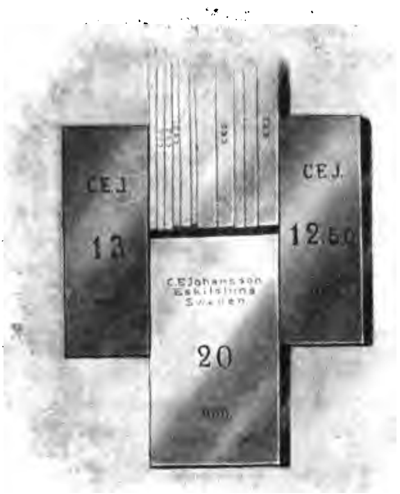


FIG. 21.

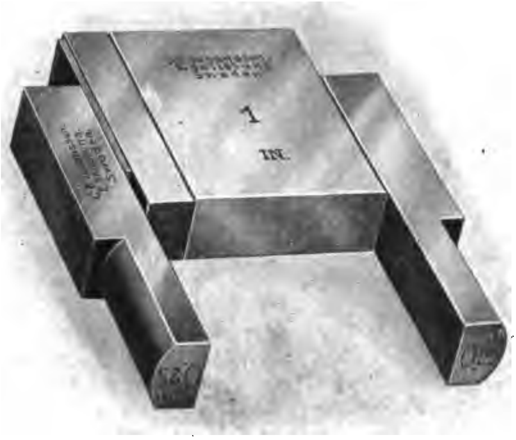


FIG. 22.

gauge can be made. When laying out precise measurement on accurate parts such as dies and jigs, the arrangement of the gauges shown in Fig. 23 may be used. By the use of these thickness gauges lines may be traced at any desired height; the sharp tool, having a long and even base, can be rigidly supported by a series of gauges as shown. This dispenses with the ordinary surface gauge or scribing block on this highly accurate tool work.

When precise work has been machined to the markings, it is customary to make very careful tests to verify the accuracy of finish, to dimensions in size and distances apart. Jigs are necessarily pieces of work demanding this extreme care, because any error whatsoever in the setting out and machining of a jig will be reproduced in all pieces of work which are tooled in such a jig. An example of a jig under test is given in Fig. 24. The horizontal slots are tested relatively by the combination gauges, and independently by the insertion of strips as shown, the great advantage of this system applied to such work being obvious.

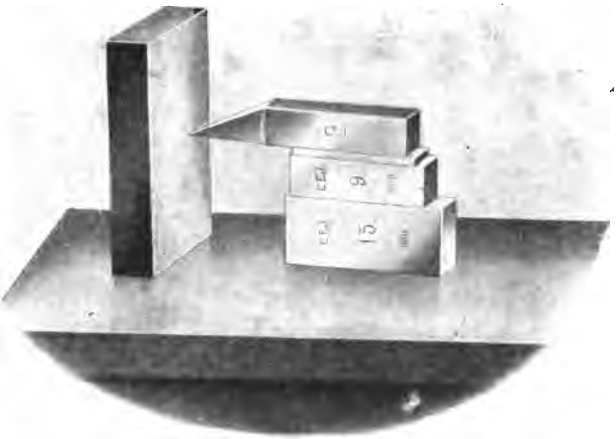


FIG. 23.

When it is desired to make pieces of work precisely accurate in thickness and to dimensions, in a vertical milling machine, the dial feed is used, and the graduations on the dial and the feed screws cannot remain constant, but are heated as though they were accurate. Here it is that the combination gauges prove most satisfactory, as also for determining the exact traverse of the machine table.

For scribing circles and curves a Centreing Point is applied on the other side of the combination that represents the radius of the circle, as illustrated in Fig. 25. This tool consists of a plain parallel piece, one surface of which is perfectly flat; and the end, which is pointed in such a way that the point which is to act as a scriber lies perfectly flat in the plane of the ground surface.

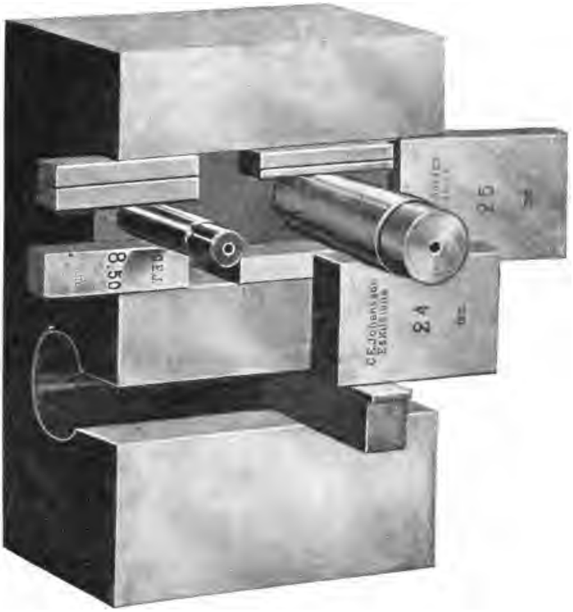


FIG. 24.

After making up from combination gauges the size that represents the desired height of the line to be traced from the base, while

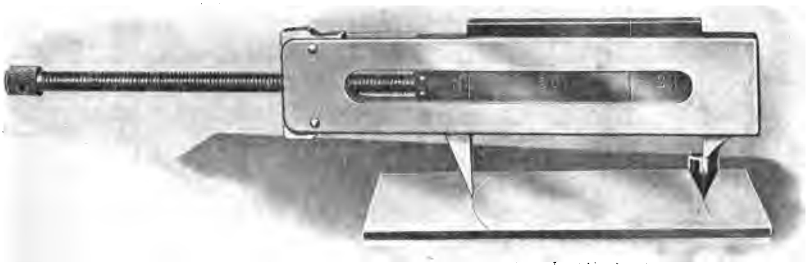


FIG. 25.

it and the work rest on a surface plate, the ground point piece is wrung on the gauge, and the scribing is effected in the ordinary way.

Fig. 26 represents a die being marked out. By this arrangement vertical adjustments are precise, the make up system being absolutely definite renders the marking perfect when once the assembled gauges are correctly placed.

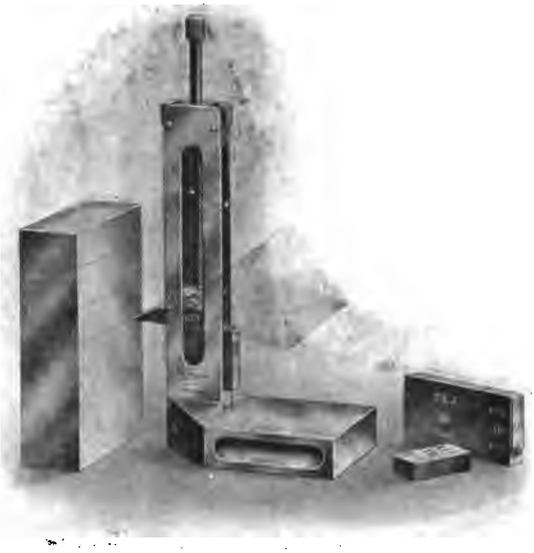


FIG. 26.

MARKING OUT HIGH-PRESSURE CYLINDER

An example illustrating the marking out of a locomotive engine cylinder is given in Fig. 27. The centre for the main bore is struck from a Y-shaped bridge, which is firmly retained in the mouth of the cylinder by means of the adjusting screws which pass into each leg. A vertical line passes through the centre which is projected to the base of the casting, this line also intersects a horizontal line drawn across the bridge which spans the lower core, and thus forms the centre for the bore.

The amount left for tooling is clearly indicated by the fine circles compassed in. On the near side a vertical strip of metal bridges the core, this has the centre of the cylinder and distance lines obtained and transferred by means of the surface gauges shown in the photograph. The various parts are indicated by letters: A = bore of cylinder, B steam chest for piston valve, C non-return valve face, D_1 D_2 steam ports to admit steam to low-pressure cylinder, E main steam inlet from boiler, F facing for pipe to conduct steam to the blower. Both the cylinder cover and the steam chest cover are fitted with 1 in. studs, the former with twenty and the latter with ten. H has a planed surface, to this the low-pressure cylinder is secured. A templet is fixed on the face A, through which the stud holes are marked; a similar templet is used on the face B, and on the face E (not shown). In boring the cylinder a stout boring bar is used; the cylinder being housed in a cradle jig very little adjustment is necessary. For the above photograph I am indebted to Henry Fowler, Esq., Chief Engineer, M. R. Co., Derby.

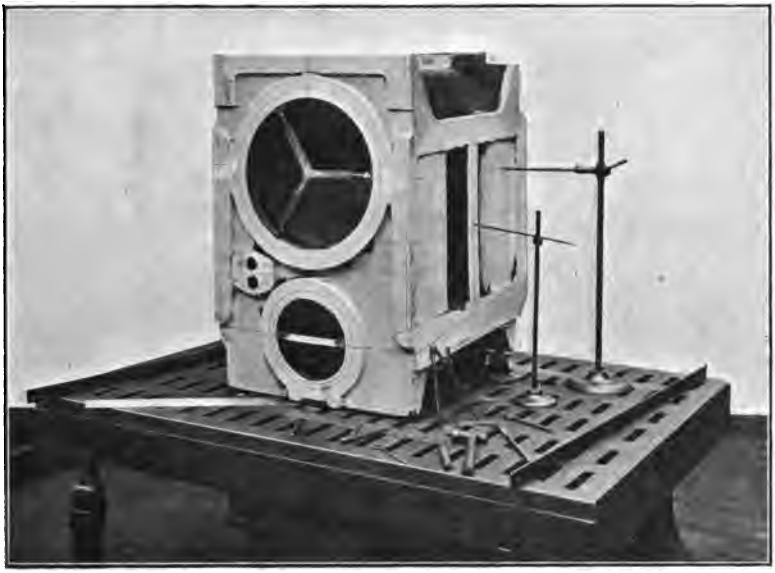


FIG. 27.—High-pressure steam cylinder, M. Ry. Co., Derby. Marking out for machining.

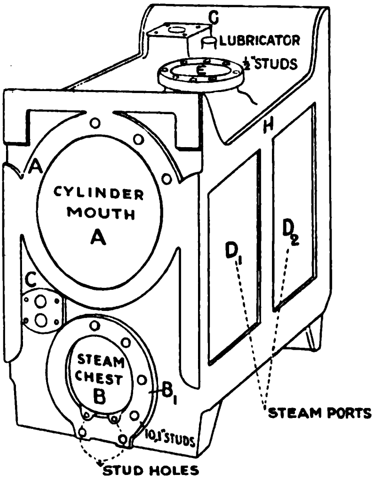


FIG. 27A.—Key to Fig. 27.

Setting Out Keyways, and Fitting Keys

Keys are usually made of mild steel, small keys are forged or milled, larger ones are forged, milled or ground. Very large keys are forged, and milled, planed or shaped. Headless keys are made direct from rectangular strips, and in this order we have such examples as are given in Fig. 33. For small work, no forging whatever is necessary.

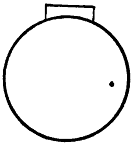


Fig. 28.—Saddle key.

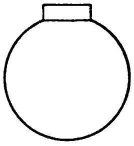


Fig. 29.—Flat key.

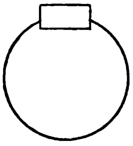


Fig. 30.—Sunk key.

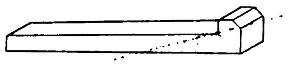


Fig. 31.—Gib-headed key.

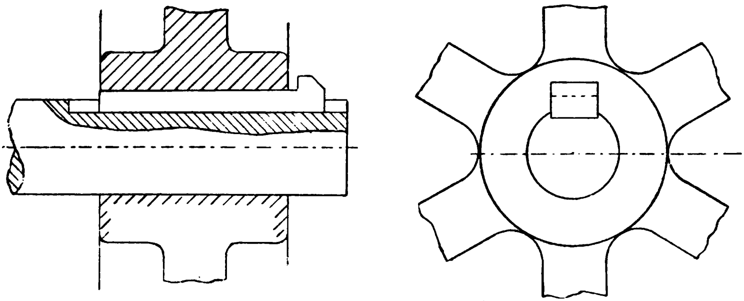


Fig. 32.—Section of wheel showing key in position.

Fig. 28 is used to locate a pulley, where the precise position can be left until other parts are arranged. Fig. 29 is a flat key, and may also (if desired) be left until other parts are fixed. Fig. 30 shows an end view of a key in its bed. A lathe fast headstock spindle is given in Fig. 34 to be marked out, and keywayed for three keys, viz., for the plate or driving-wheel, the steel cone, and the change wheels respectively. This example is one of many similar spindles, or shafts, which have to transmit great power and retain their original true running at the same time. To possess these two qualities precisely, means the perfect fitting of each key, and true alignment of each keyway (Figs. 31, 32). To mark out the keyways the spindle is placed in a truly horizontal position, resting on two Vee blocks. Then a line is drawn with a scribing block (Fig. 35) across the ends to obtain the centre. This line is then transferred to the three parts affected, and will be the centre line for each key. The width of the keyways can now be set by the surface gauge finger, *i.e.* one half above and one half below the centre line. This will be done for each, and the respective lines lightly dotted. Then the spindle can be slot drilled, and the work is ready for the keys to be fitted. This requires a skilful workman, or the desired results may not all be obtained.

Keys which require very little correction can now be purchased, or keys made from "Stubs" steel can be fitted direct. Whichever method is adopted the fitting of the keys is a most important operation. It is necessary in the first instance to notice that the keyways are cut centrally, both in the shaft and in the wheels to be keyed on. Errors in this particular must now be corrected, *i.e.* if a keyway in a shaft or wheel wanders out of a straight path its amount of error can be plainly detected when the parts are brought together, and usually a few strokes of the file will be sufficient to bring them into alignment. This being

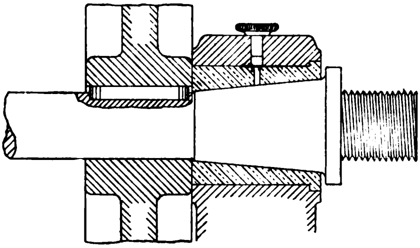


FIG. 33.—Headless key securing gear wheel to lathe spindle.

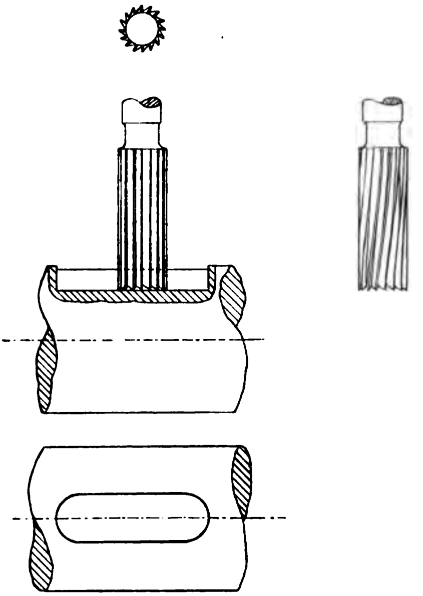


FIG. 33A.—End mill teeth having spiral.

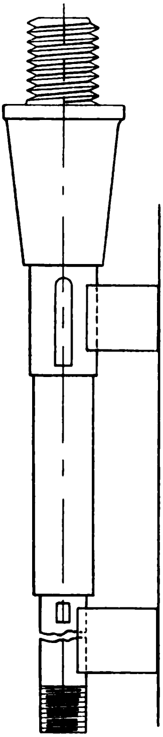


FIG. 34.—Setting out keyways in lathe spindle.

done satisfactorily, the length, depth, and width of the key can be gauged exactly. The measurements thus obtained can be transferred, and the dimensions of the required key fixed by the sliding caliper gauge (Fig. 36), and a pair of "outside" and "inside" calipers respectively (Figs. 37, 38). *Trial fitting* of the steel key in its shaft and wheel need not be attempted until the measuring instruments agree that there is only a very small amount of excess in the key's bulk when compared with the keyways it has to fill. Now the plate wheel is a *driving fit* on the spindle before any attempts at keying are done. This is imperative for two reasons, primarily to assist the driving power or capacity of the wheel, and secondly, to ensure that the keying on shall not disturb the actual coincidence between the outer circumference of the spindle and the inner circumference or bore of the wheel.

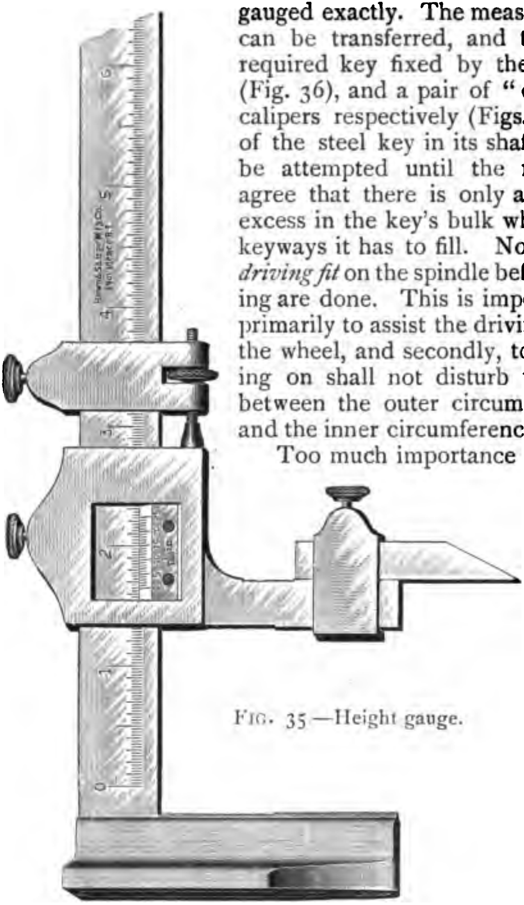


FIG. 35—Height gauge.

Too much importance cannot be given to the following points:—

1st.—Perfect fitting of the shaft and wheel.

2nd.—True alignment of the keyways.

3rd.—True fitting of the key in its seating in the shaft.

4th.—True fitting of the key in the wheel on both sides, from end to end; and lastly,

5th.—Even touching on the top of the key from end to end when in place, however long the surface contact may be.

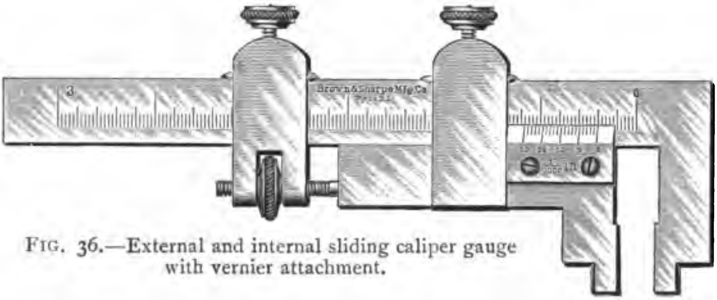


FIG. 36.—External and internal sliding caliper gauge with vernier attachment.

There is no deviation admissible without sacrificing the truth of the wheel when revolving, or of the permanent power of the wheel to drive.

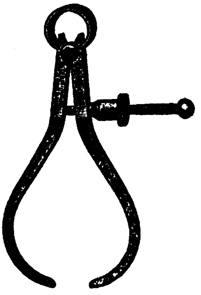


FIG. 37.

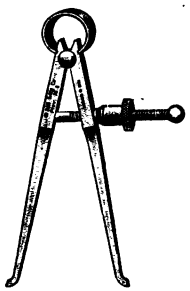


FIG. 38.

There is a risk in relying on "one's judgment" in fitting keys, and it may be pointed out that a sliding caliper gauge (Fig. 36), properly used, makes accurate fitting at the vice quite as reasonable to expect as a shaft or spindle from the latheman who usually gauges his work so precisely as to guarantee its correct fitting when once removed from between the lathe centres. In modern practice, fly-wheels are turned and bored simultaneously at the same setting, therefore the wheels are quite true before they are fitted to their respective engine crank-shafts or other shafts by being forced on and properly keyed, and there will be no appreciable amount of error when the engine is started and the wheel revolves. Now let it be supposed that the wheel is a "sliding fit" on the shaft instead of a "tight fit," then when the keying up is done there will be an appreciable error in the periphery of the wheel, and one which can only be corrected by trueing up in place, which is not permissible or practicable. In another case the keyways are not in perfect alignment from end to end, and the key is fitted nevertheless. The shaft may be bent, and thereby cause the wheel to oscillate, or the wheel will be considerably out of truth when the shaft is set revolving. A final instance may be cited when by "trial fitting" the key has been too much reduced, and is only a driving fit, somewhere near to the head the result will be that the fly-wheel will wobble considerably from side to side, and thereby cause the engine to be out of true balance. Apart from this serious defect, there will be an irregular strain on the bearings, and the danger, owing to the centrifugal force, of the wheel working loose on its key, and possibly doing other serious damage to the working parts of the engine. There are still one or two points of importance. With reference to placing the keys in their seatings in the lathe spindle. It is necessary to see that each key rests evenly in its bed when forced into it. The key and spindle may be distorted by hammering, indeed, it is unsafe to hammer the top of the key unless the *spindle is properly supported immediately beneath the keyway;* experience shows that the truth of the spindle can be lost in driving in the keys unless it is placed on a solid support for each key respectively. When practicable the key may be forced into its seating by placing the parts between the jaws of a parallel vice. Fixed in this manner there is considerably less risk of bending the shaft or spindle. (See Sunk Key, Fig. 33, and Milling a Keyway, Fig. 33A.) Sometimes the object has to travel for a comparatively short distance, here the key is secured to the shaft, and the keyway cut in the part intended to slide over the key. Such parts of a mechanism, which have to slide on as well as rotate with their shafts, are provided with a "feather key," the key being thus secured to the object which has to slide, especially when the movement along the shaft is for a considerable distance, the keyway being cut in the shaft. Parts which are intended to rotate permanently together are secured by gib-headed keys (Fig. 32). In heavy work there may be two such keys, fixed in keyways, located at right angles to each other.

Colliery winding wheels, and other very large wheels, are secured to their shafts by several keys. The core in the centre of these wheels is of a larger diameter than their respective shafts. In such cases the driving in of the keys locates the rim of the wheel. To effect this the keys are driven in deeper or shallower as required until the rim of the wheel becomes concentric with the shaft which supports it, and balanced equally on the sides as well. Referring again to Case 1, claw clutches are familiar examples of this arrangement. A sliding lathe saddle (Fig 39), carrying a worm along the keyway on the back shaft is an example of the second case. Fly-wheels and large gears, also pulleys, are instances of the third order. When a gib-headed key is driven into place it is sometimes necessary to cut the key-head off flush with the end of the shaft. Instances of this kind occur in bevel and other gearing where the key-head would be dangerous if left on. There is, however, considerable difficulty in withdrawing such keys, as there is frequently no means of inserting a key-drift; generally these wheels have to be pulled off or the shaft driven out through the wheel, leaving the key intact in the wheel. If, however, this cannot be done, the key must be drilled out with a rachet brace specially rigged up.

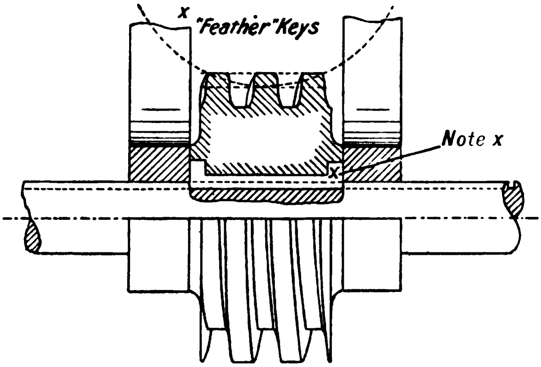


FIG. 39.—Worm on back shaft of lathe.

KEY-SEATING MACHINE

In the keyway cutting machine, a considerable improvement is made over the slotting machine, in the latter the tool nose usually tends to spring away from the surface of the work while cutting. This is especially the case when slotting deep holes, when the ram to which the tool is attached travels a considerable distance from the slide which supports it. In the former a solid support is provided to the tool for the whole length of its cut or stroke. The work is chucked by its bore, so that the walls of the hole are always parallel with the tool slide or guides, and the cutter bar, carried within it.

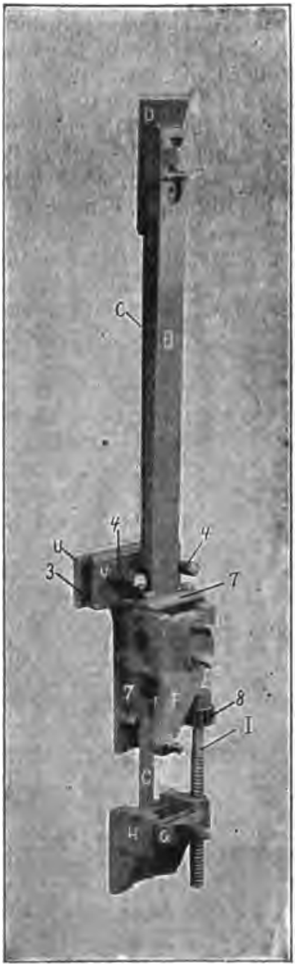


FIG. 40.—Key-seating attachment.

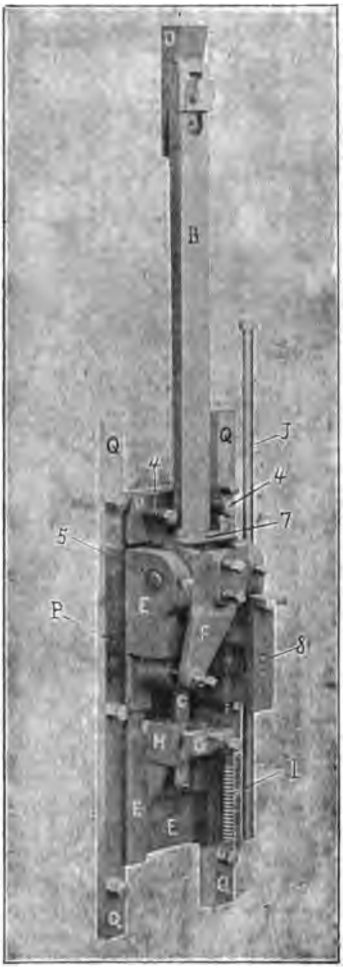


FIG. 41.—Key-seating machine cutter bar and attachments.

Held in the above manner the face of the boss is not a factor, and in some cases is not even tooled over. A wedge, D (Fig. 40), tapered

$\frac{1}{8}$ in. per foot is placed in the tool post, just at back of the tool to give the usual draft to the keyway. As the work changes in diameter, expansion bushings are used, a series of which are required to fit the various sized holes to be keywayed. One bushing rests at the bottom of the post, and the boss of the work to be keywayed is then placed in position on the post, resting on the lower bushing. The upper bushing is then placed on the post, and thus it brings the hole in the boss precisely in alignment, therefore the keyway can only be cut in a straight line. The makers, Messrs. Mitts and Merrill, claim that a keyway $\frac{1}{2}$ in. wide, $\frac{1}{4}$ in. deep, by 6 in. long, can be cut, and the work removed in two minutes. The detailed working of the machine is fully explained by the descriptive matter, with letters of reference attached (Fig. 41).

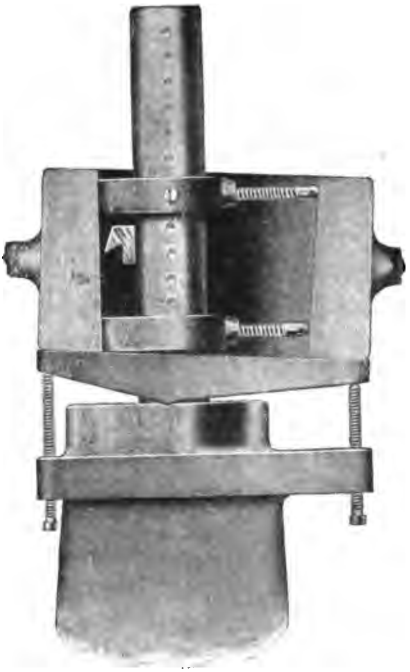


FIG. 42.—Keyway cutting in taper work.

Key-seats in taper holes are conveniently cut on the above machine as illustrated in Fig. 42. Special taper bushings, a post-turned taper, or the solid bushing may be used to chuck the work. It is necessary that the side of the hole be placed fairly against the front faces of the solid bushing and held there, while the key-seat is being cut by the jack screws, blocks, or a wedge of proper taper. Therefore, the work, whether taper or straight, is chucked by the bore, and the key-seat is cut as accurately as the work is chucked. The above example shows one method of chucking a taper hole, and the use of the bolster for supporting heavy work. A drawing is given in Fig. 43 illustrating the important working parts. The chief advantages of this arrangement are the very solid support given to the tool post, and the axial centring of each piece of work by its own bore, by means of the bushings.

DESCRIPTION OF PARTS

A—Post, grooved to receive tool bar. Made of various lengths and diameters.
B—Tool bar with ratchet teeth at lower end to engage tool bar holder F. The tool bar can be of any length.
C—Feed wedge bar. Made of any length to correspond with the tool bar.
D—Feed wedge moves the tool forward, supporting it continuously while cutting.
E—Crosshead, driven both ways by the pinion. Its stroke is regulated by setting the tappet collars T on rod S. It has an automatic quick return motion.

F—Tool bar holder attached to crosshead by trunnion pins 5, on which it has a slight vertical motion. On the up stroke F drops slightly and the tool is relieved.

G—Clamp block for feed wedge bar.

H—Wedge bar holder. It is tapped to engage screw I, by which it is moved on the crosshead to move the feed wedge up and down.

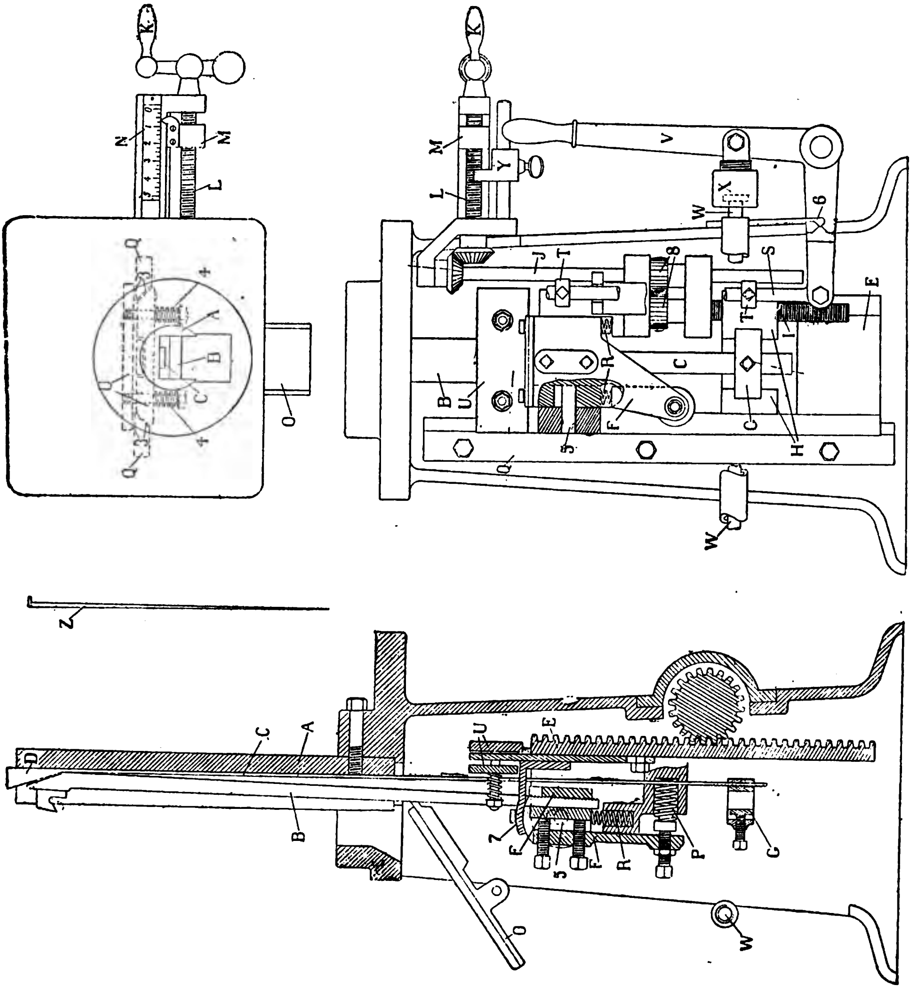


FIG. 43.—Key-seating machine.

I—Screw to operate H. It is rotated by the handle K in connection with the mitre gears, splined shaft J and gears 8.

J—Splined shaft which turns the feed screw I.

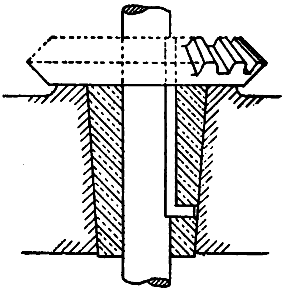
K—Handle which feeds the tool by moving the wedge D.

L—Feed screw on which the indicator nut works.

M—Indicator nut, which shows on the scale the motion of the wedge D and the depth of the keyway.

N—Adjustable scale to indicate depth of cut. The zero mark of scale is set under the pointer when the tool begins to cut.
P—Spring to hold tool bar B back against wedge D.
Q—Slides which guide the crosshead E and on which the friction clamp U grips, to give the automatic relief to the cutter.
R—Springs which support the weight of the tool bar B and holder F.
S—Tappet rod, which automatically operates the reversing friction clutch by means of the lever V and rod W.
T—Tappet collars, which, when struck by the crosshead, move the rods S and W.
U—Friction clamp, which grips the slides Q with the hard fibre blocks 3.
W—Rod, which extends through the hollow shaft, to shift the friction clutch.
X—Adjustable brass coupling in which the head of the rod W revolves.
Y—Stop gauge, adjustable to stop the nut M at any depth of keyway in making duplicate pieces.
Z—Taper wedge, which is fastened in the post A behind the wedge bar C when taper keyways are to be cut.
3—Hard fibre blocks, fastened to friction clamp U, to provide a soft wearing surface.
4—Springs to give uniform pressure to friction clamp U on slides Q.
5—Trunnions, fastened in crosshead and projecting into the slots on either side of tool bar holder F, which allows a slight vertical motion of holder to relieve the cutter on the up stroke.
6—Spring which holds and gives force to movement of lever V.
7—Relief bracket, connects tool holder F to friction clamp U by which tool bar B is moved down on wedge D to relieve the tool on upward stroke.

A special form of key is given in Fig. 44. Here the key is just held within the bore by means of a small-turned nug, at right angles to the key proper. This arrangement is very satisfactory for a vertical-drilling machine in which the spindle may work freely up and down while the key is self-contained in the bevel gear, and, therefore, clear of any bearing.



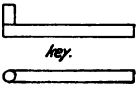


FIG. 44.—Gear wheel riding on drilling machine saddle with nug key.

The use of a key-seat rule is given in Fig. 45, in marking for a key-seat in a shaft, and in Fig. 46 an example of chipping out of solid with a cross-cut chisel such a keyseat at the end of the shaft. A similar key-way, but marked out with the aid of a scribing-block and try-square, is given in Fig. 47. In this case the shaft lies in Vee blocks supported on a true plane, while the marks may be transferred to any other part of the shaft for similar key-beds or for shafts of a like diameter. In the latter case the lines

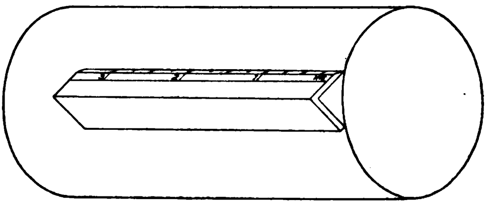


FIG. 45.—Key-seat rule.

may be set and the scriber-finger retained; if two scribing-blocks are used the setting will be accomplished much more quickly.

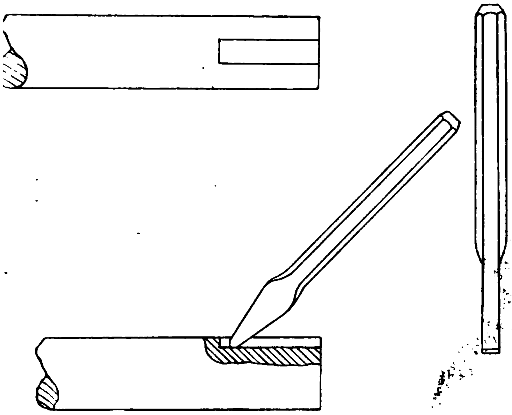


FIG. 46.—Chipping keyway with cross-cut chisel.

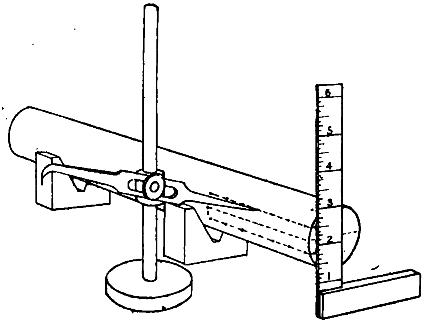


FIG. 47.—Marking out keyway in shaft.

A direct use of the scribing-block occurs when the key-seat must be marked precisely accurate relative to some other work, such as an eccentric on a crank shaft.

Marking Out or Dividing in the Lathe

Dividing may be done in the lathe in several ways, one by having a front gear wheel drilled with several rings of holes and an index pointer attached to the side of the fast-headstock. In this arrangement there is a small screw fitted in the headstock and a slit sawn in the screw-head permitting a flat piece of spring steel to enter. A hole is drilled at right angles and a pin is inserted which allows the spring steel to swing; but by having a nut and washer the sides of the slit in the screw-head may be drawn up and thus put a tension on the movement of the index finger as desired.

A turned pin slightly taper is fitted as shown in Fig. 48, and made to stand off from the face of the finger about $\frac{3}{16}$ of an inch, a button or other suitable form of head on the opposite side of the finger serves to regulate its movement. Four rings of small holes, viz. of 96, 90, 63, and 33 respectively, will be sufficient for ordinary purposes, from these we may divide a piece of work into 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 parts, etc., as required. The above may be conveniently arranged for a lathe of 5 in. or 6 in. centres, but with a larger plate wheel having a wider margin of metal to work upon any special divisions could be arranged for. This work, however, is now conveniently done in a "dividing engine" or, failing that, a "gear-cutting" machine, or on a milling machine. Work to be divided, and riding evenly on centre points must be properly driven, and a finely pointed tool fixed precisely on the centre line. There should be little effort required to rotate the lathe spindle and work by hand so that the pin may enter and fill each of the correct holes exactly as they are brought in position. To bring the wheel right with the proper hole in position necessitates a very steady movement or the wheel may be rotated a little too far; should this occur, it is not a wise course to return the wheel backwards and then insert the pin, by so doing the driving of the work may be slightly changed in position relative to that of the plate wheel, with the result that should a division line be made, it will not be accurately located.

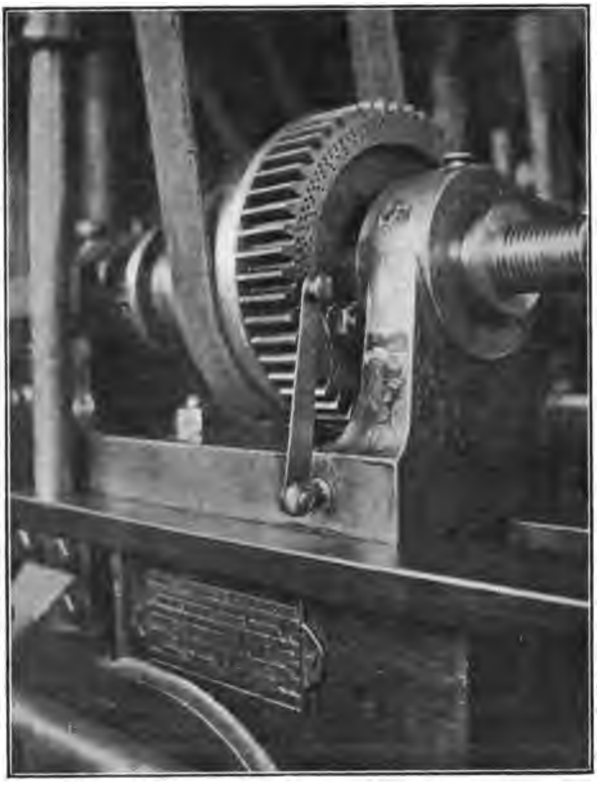


FIG. 48.—Divided wheel in lathe headstock.

A better plan is to make a complete revolution and slowly bring the hole required immediately opposite the index pin. The graduations on machine slides, shaping-machine heads, dials, etc., are examples of work done by the above method.

LATHE "MANDRELS." HOW THEY ARE MADE AND USED.

A mandrel is a short shaft or rod of cast steel turned precisely true, finished a tight fit to the standard, parallel for the length of the work it is to support, beyond which a minute taper is turned to act as a grip. A considerable portion of bored work has to be mounted again in the lathe to be turned or in some cases ground, or milled, in the grinding machine, or milling machine, as the case may be. Usually the external tooling or grinding is concentric with the bore of the work, whether the surfaces thus produced are parallel, taper, or in steps. Now to ensure this precise uniformity of rotation or movement of the external surface relative to the internal or bore of the work (concentric running) mandrels of a guaranteed accuracy are necessary to support and carry the work while it is held between the centres of the lathe, the grinder, or the milling machine. The present system of working has demanded that all bored holes shall be accurately reamed and parallel to standard gauge, and essentially a corresponding exactitude in the mandrels, both in dimensions and truth in running, is desirable. For the above reason, reputable firms are now manufacturing mandrels of a high precision. In making a plain mandrel a piece of tool steel is cut off, faced, and very carefully centred to 60°, 75° or 90° according to the lathe centre points (the general angle now being one of 60°). At the root a small hole is drilled to prevent the centre point being worn, and also to furnish room for the lubricant. (See Figs. 49, 50, and 51.) The shaft is turned about 0·020 over size, the ends being reduced and flats machined to provide a seating for the carrier screw, the piece is next hardened and tempered. Any irregularity in the centres is removed by means of a lead or copper lap smeared with flour, emery and oil (see Fig. 108), the cone point of the lap agreeing with that

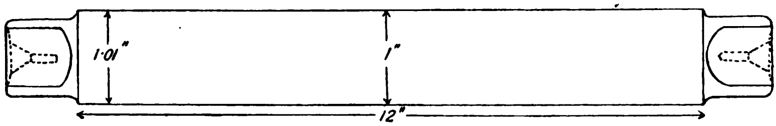


FIG. 49.—1-in. standard mandrel.

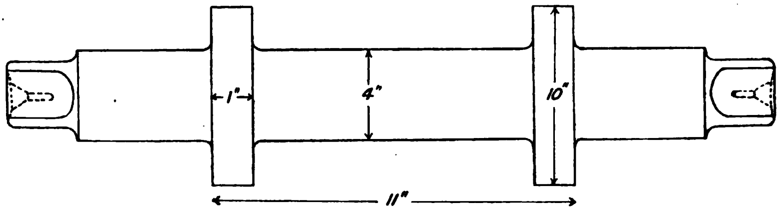


FIG. 50.—Collar mandrel.

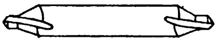


FIG. 51.—Slocomb centre drill.

of the centre. The mandrel is next mounted in a universal grinding machine and ground to precise dimensions, the progress being ascertained by means of a micrometer reading to 0·0001 inch. For a distance equal to the length of the work to be turned the mandrel is ground parallel, after this a very slight taper is put on, viz. 0·01 in. per ft., an amount found in practice to be ample for work properly reamed to standard gauge. Temporary mandrels, such as may be turned for special or odd jobs, are often made on the ends of mild steel shafts and invariably too much taper is allowed, therefore greater force is exerted in fixing the work than should be necessary. While turning the work sometimes it slides off, and the mandrel is driven, or forced, further in to obtain a better grip; this is disastrous to the mouth of the bore, and if the work is particular it should not be proceeded with until the taper on the mandrel has been made more gradual; unless this is done the boss on the work will most likely be fractured.

There is a mistaken idea abroad that a mandrel must be tapered slightly from end to end; and we will take for example the table for a small drilling machine 20 in. diam. with a sleeve $8\frac{1}{2}$ in. totaling a bore $1\frac{1}{2}$ in. × 10 in. long, the work bored and reamed parallel, and a taper mandrel driven or pressed into it, the work being mounted between the centres and turned. Now it is obvious that the small end of the mandrel will be a shade less than a sliding fit, and therefore will not be directly in contact with the walls of the hole, but the opposite end is tight fitting, and since the work may be actually driven instead of the mandrel no trouble or error will be noticed; but remove the mandrel and force it in from the opposite end, the plate or table will now certainly show some error as it rotates, the greater the diameter of the work and the longer the bore the more the error is multiplied. Expanding mandrels (see Fig. 53) are intended to obviate the above defect by having a parallel fitting bush or sleeve which is made to fill the bore of the work uniformly. The mandrel is turned to a certain taper, and the bush bored to a precise counterpart. Referring to Fig. 53 (4) it will be seen that the bush is slotted in several places which permit of an expansion as the mandrel is forced within it. There is essentially the same care bestowed in turning, hardening, and subsequent grinding as in the mandrel previously considered.

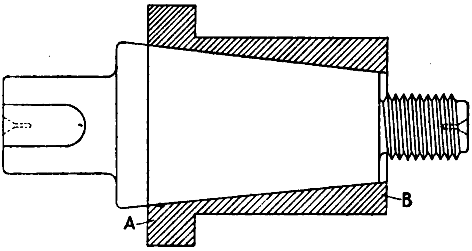
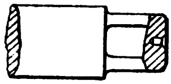


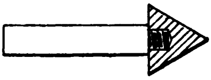
FIG. 52.—Cone bush mandrel.

Conical mandrels are also largely used to turn up the bearings for lathes, milling machines, etc.: these are made in two forms. Fig. 52 shows one type with a taper plug fitting the work, the frictional contact is usually sufficient to hold the bush whilst it is tooled. This mandrel, if properly used and cared for, is only second to that of turning up the bushes in place on their own spindles (a practice which cannot be excelled obviously, as by so doing it is impossible for error to creep in).

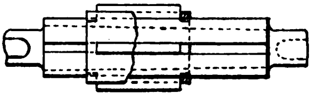
In lieu of this, the mandrel shown in Fig. 53 (7) is used—the figure explains the construction; it may, however, be added that taper work is usually faced at A before boring, *i.e.* while it is chucked, but the remaining face B must be tooled on the mandrel. It will be seen that if the face B happens to have any irregularities in the casting they will in all probability alter the concentric fitting of the work. In such mandrels the parts should be hardened and ground, and whenever practicable the face B should be tooled before it is mounted. This reference to facing the end of the work must also be understood to serve another purpose, Fig. 53 (7), for instance, carrying a bush, which may not be fixed evenly on the mandrel; if, however, it has one face tooled, the error in fixing may be rectified by adjustment, but, when neither



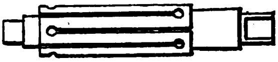
1
Parallel mandrel.



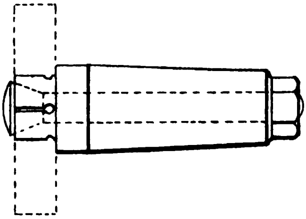
2
Cone-pointed lap.



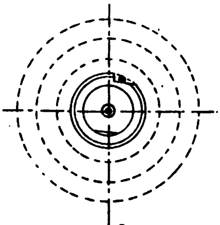
3
Expanding mandrel.



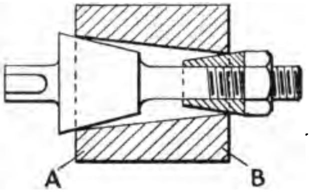
4
Expanding mandrel.



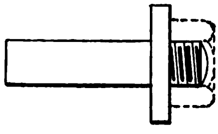
5
Slit pin with cone head.



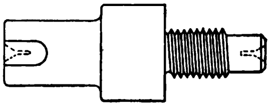
6
Mandrel with rod in recess.



7
Cone mandrel.



8
Nut mandrel.



9
Screw mandrel.

FIG. 53.

surface has been tooled, and error in running is noticed, correction is a very difficult, and may prove in bad cases an impossible task.

It should be remembered that work thus held between very taper cones, actually touches only at a point, and that any hammering to alter the position of the work will at once cause the mouth to assume an eccentric or elliptic form, which is obviously fatal to accurate work Two forms of nut mandrels are shown in Figs. 53 (8) and 53 (9). The thread should fit the work or the turned faces will not be true.

METHODS OF FORCING THE MANDREL INTO THE WORK

Before attempting to turn any work on a mandrel the piece should have a straight hole by truly boring, and if need be the hole should be ground, or lapped out truly. There are several ways of making a mandrel secure. Very light work may be driven satisfactorily by striking the end with a block of hard wood, and hand hammer. Medium sized work will require a lead mallet. Heavy work is only made secure when the lead mallet is struck with a sledge hammer.

METHODS OF SECURING MANDRELS

A much better result is obtained by the use of a Mandrel Press, one form of which is given in Fig. 54, designed for light work such as pulleys, etc. Forced into the work in this way the mandrel faces and centres are uninjured.

To protect the centres from bruising, the faces are made concave, so that if by any chance the mandrel end should be struck the centre hole will be protected. When once a bruise is made near the centre hole the mandrel will be caused to revolve eccentrically, and can only be restored after considerable trouble. For this reason *mandrels are never struck with a steel hammer* for any purpose whatsoever.

Work above 4 in. or 5 in. bore is usually mounted on mandrels of cast iron, but to prevent the centres wearing away holes are drilled and plugged with steel, the centre holes are then made in the usual manner. Mandrel diameters can quickly be increased by having suitable collars, thus small steam engine cylinders, and similar work up to 12 in. or 15 in. bore, can be mounted on a collar mandrel, while the faces and flanges are turned and bored. The collars may be forged, keyed, shrunk, or cast on to the mandrels in position according to the size of the bore in the object to be turned, and at proper distances apart. (See Fig. 50)

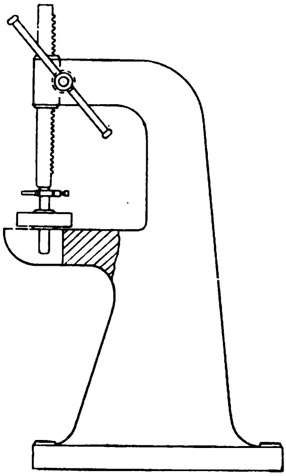


FIG. 54.—Mandrel press.

For very heavy work the mandrels are forced in position by hydraulic pressure in a similar manner to that of fixing driving wheels on locomotive engine crank shafts, and webs of built-up cranks.

EXPANDING MANDRELS

An expanding mandrel of a special form is shown in Figs. 54A and 55. It will be seen that the mandrel takes a direct bearing in the conical hole at the mouth of the spindle, and is retained by a fine thread well within the spindle bore, thus making it rigid. This arrangement is a decided improvement on the mandrel fixed between the lathe centres, especially for light work requiring to be faced, topped, or undercut to precise dimensions, and true running. The working parts cannot well get out of order, since they are hardened and ground. By having the end clear, the changing and tooling can be quickly effected. The work is liberated or secured by the simple movement of the collar screw, and is another instance of accuracy in securing and of quickly handling the work. The mandrel is adapted to the Pratt and Whitney lathe spindle, and is of their manufacture.

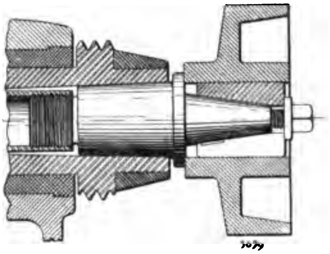


FIG. 54A.—Expanding mandrel.

Fitting in a similar manner is the expanding mandrel shown in Fig. 55, or it may be left entirely to the frictional contact by the conical fitting portion. The relatively small diameter of the screw which holds the bushing in place makes it possible to counterbore or chamber the end of a hole without using a hook tool. These mandrels carry the work on six points in the surface of a cylinder, concentric with the spindle axis, and consequently work will run dead true on a straight spindle, which cannot be assured when similar work is turned on a tapering mandrel, between the lathe centres.

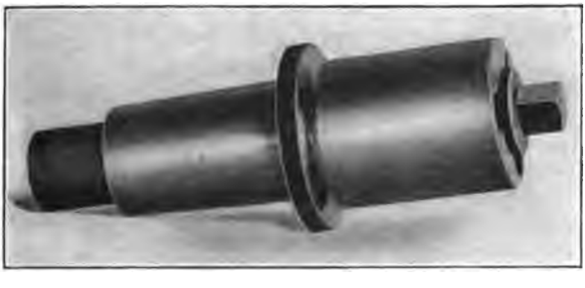


FIG. 55.—Expanding mandrel.

Holding Appliances

The following items should be of interest to beginners: When about to fix a piece of work for machining, the bolts, nuts, washers, and clips should all be at hand. The nuts should be known as good working fits on their respective bolts before any securing is attempted. The bolts should be oiled, so that the nuts cannot "seize," and so destroy the threads.

Washers must always precede the nuts; this serves to keep the bolts from moving, and also prevents the corners of the nuts from jamming in the clips.

Very light work may be satisfactorily carried by the use of $\frac{3}{8}$-in. bolts, light work may have $\frac{1}{2}$-in. bolts, medium work $\frac{5}{8}$ in., heavier work $\frac{3}{4}$ in., $\frac{7}{8}$ in., or 1 in. diameter bolts, depending, of course, upon the amount of metal to be removed, and in some cases upon the dimensions and weight of the object to be tooled up.

Generally mild-steel bolts are used, but where iron bolts are used they should always be made from the best brands. All bolts should be periodically annealed to restore them after fatigue, *i.e.* to eliminate the internal stresses caused by constant use; the bolts should be very slowly heated to a red heat, and then slowly cooled down. Those showing defective threads should be shortened and re-threaded; this considerably lengthens their life, and keeps them in good condition generally. The bolts having square necks are to be preferred, as these are not so likely to move whilst being secured. The clips are simplest and best when formed from rectangular bars of mild steel. Obviously, the clip nose should be well on to the work, and the work should touch the table or plate immediately beneath the nose of the clip, or suitable packings should be inserted if there are projections preventing direct surface contact. The bolt can exert most pressure on the work when placed as near as possible to it, and conversely the bolt can exert least pressure when placed as far as possible from it. Therefore the holding power of the bolt is just proportional. For this reason solid bar clips made with a hole near the nose are less liable to be misused than the common horseshoe clip, which permits the bolt to be located anywhere along its length. A further defect in the horseshoe clip is that the opening is generally much too wide; perhaps this is caused by the desire to have a clip useable for the heavy as well as the lighter work, *i.e.* to admit $\frac{1}{2}$-in. or $\frac{3}{4}$-in. bolts. To expedite the fixing, a screwed hole is made near the extremity of the clip to receive a bolt or screw of the length required; this readily serves as a support to the opposite end of the clip to keep it straight (Fig. 56). Wooden blocks, however, are best of all for heavy and medium work; placed endwise, the wood blocks act as cushions, and the clips take a firm grip on them. Placed across grain is bad, and usually the clips sink, and are, therefore, insecure. Large pulleys, and engine fly-wheels, can quickly be secured by gripping their alternate arms on to three wood blocks, previously hollowed out to fit. Held to the plate in this manner the rim may be tooled on the face and sides, and the boss

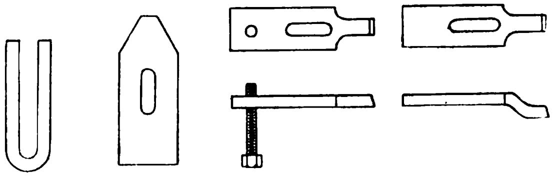


FIG. 56.—Clips in ordinary use.

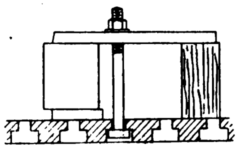


FIG. 57.—Correct method of fixing work.

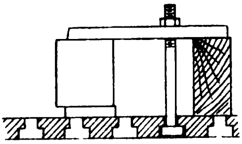


FIG. 58.—Incorrect method of fixing work.

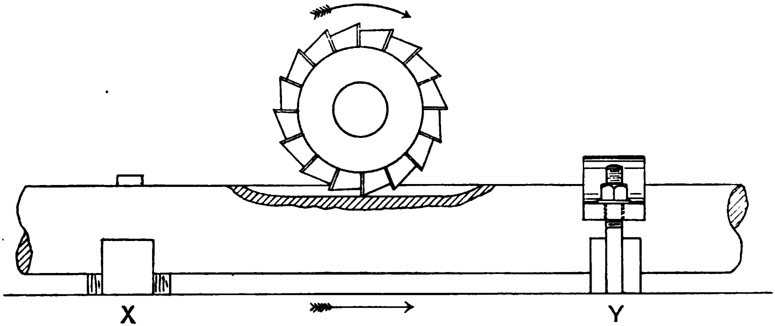


FIG. 58A.—Milling short keyway in shaft.

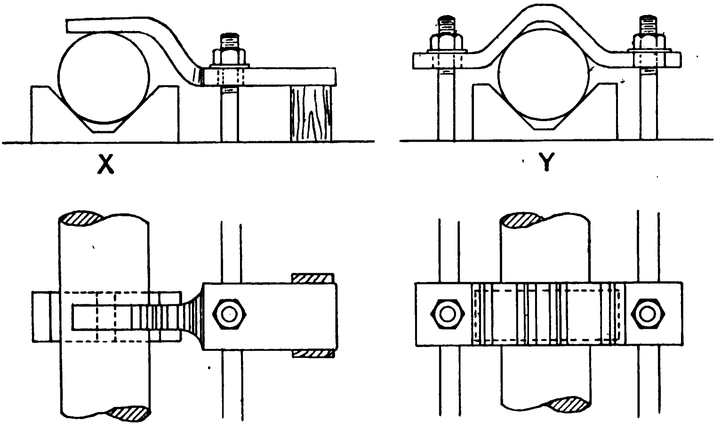
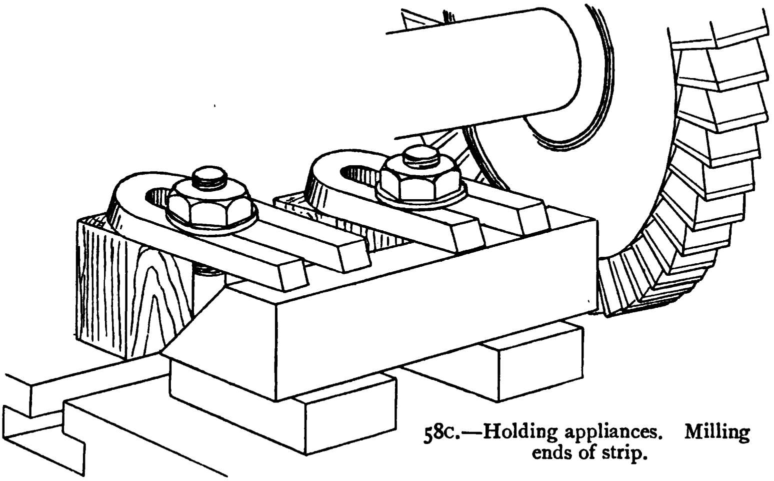
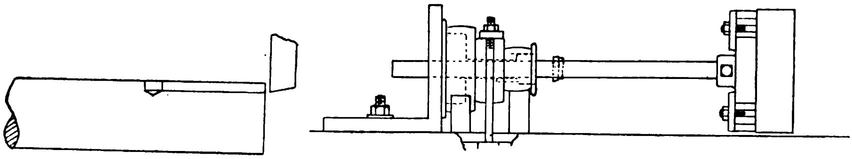


FIG. 58B.—Showing two methods of securing work to machine table.

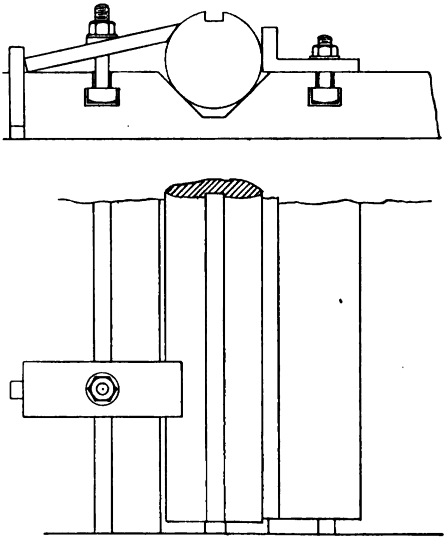


58C.—Holding appliances. Milling ends of strip.



58D.—Planing keyway in speed cone.

bored simultaneously. There will be an increased bite, therefore less liability for the work to move. For this work there is an advantage in the modern hollow-spindle lathe over those turned solid, inasmuch as the cutter bar may be housed in the spindle or bushing, and thus prevented from vibrating during the boring and finishing processes. This principle is most successfully seen in boring deep holes. Where the bar enters a bushing in the fast headstock spindle, the bushings may be interchanged as different sized bars are used. Similar work bored in the lathe with the cutters fixed at the end of the bar necessitates much



58E.—Planing long keyway in shaft. Method of securing work.

slower speed and feed, consequently less work can be done in a given time. Forms of clips and method of fixing are given in Figs. 56, 57, 58, 58A, 58B, 58C, 58D, 58E.

CLAMPING ARRANGEMENTS

A special form of machine vice is given in Fig. 59, in which any desired length of work may be accommodated within the capacity of the machine table. This divided vice has some novel features, combining a parallel and a downward movement. The jaws are capable of accommodating the work, and forcing it down on its supports.

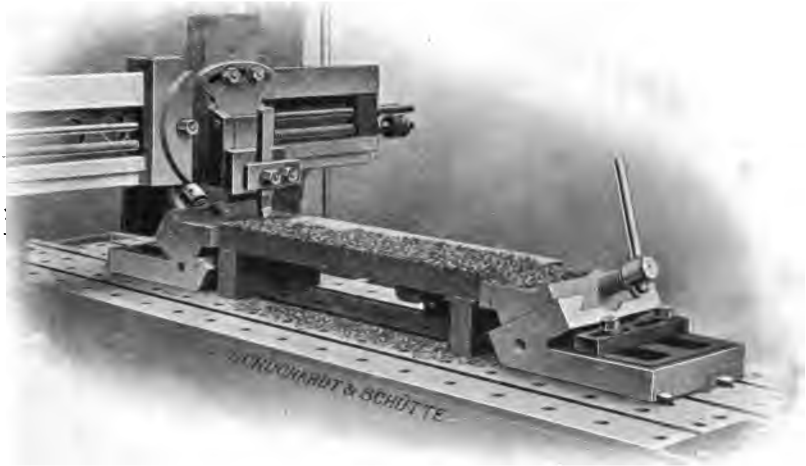


FIG. 59.—Two-part vice holding rectangular plate.

This is a most desirable thing, especially when planing or shaping thin plates, which it would be wrong to hammer in order to get them to pad evenly on their supports. An example is shown where a stout plate of cast iron is gripped between the serrated jaws of steel, the length of the rectangular plate being much too long for an ordinary machine vice to take in. It would, therefore, have to be otherwise wedged up between stops, obviously offering much difficulty to obtain a truly even base. This difficulty, however, is increased when the work is reversed and the tooled face laid downwards.

Another case is given in Fig. 60, illustrating the securing of a cast-iron cap while the bolt holes are being drilled. It will be noticed that the arrangement is adaptable for repetition work of the above character.

The vice being secured firmly to the machine table, there is only one screw to be released to liberate the work. Of course, there are parallel machine vices made with an equally quick movement of the loose jaw, but in these their holding capacity for length of work has limitations.

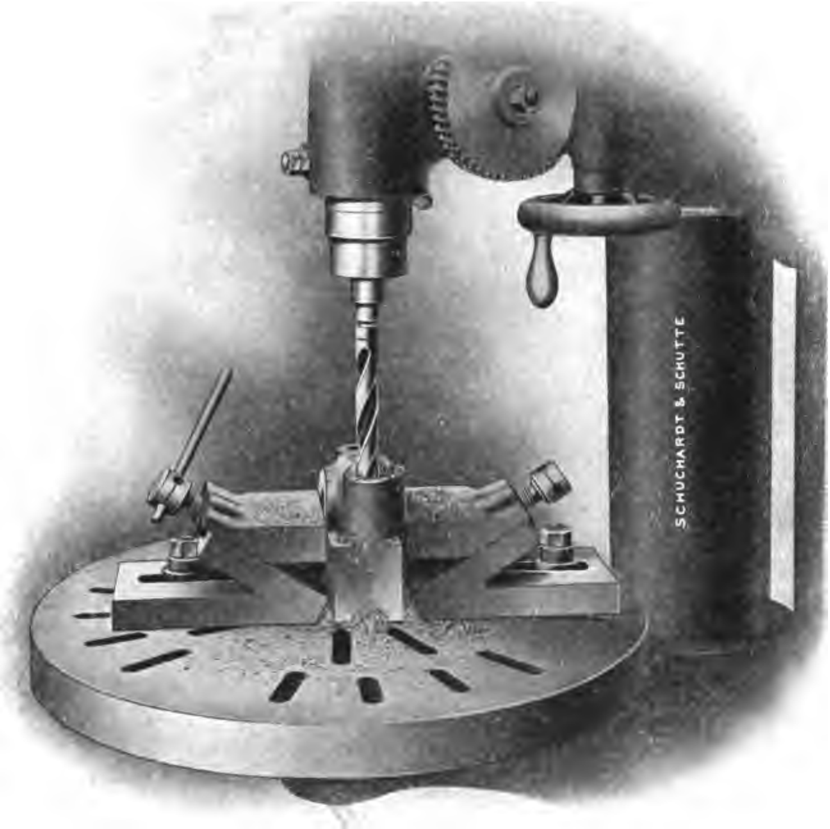


FIG. 60.—Two-part vice holding work for drilling.

Referring to the above figure, it will be seen that the thrust is at an angle, tending to hold or force the work downward, an advantage over a purely horizontal thrust, where there is no reliance upon the jaws gripping an iron casting or forging so that it will lie true to the marking-off lines at every point. To assist the operative in setting the work, the pieces should be made fairly even on the sides which are to be gripped by grinding off any prominent parts or on irregular faces.

MACHINE VICE

After securing small pieces in the machine vice, there is a tendency for the work to tilt out of line during the tooling stages. For this reason the jaws are slightly wider open at the bottom than at the top, so that the work will be drawn down hard upon a parallel strip or true block. There should, however, be little reliance placed upon the support thus obtained; the actual grip is between the vice jaws, *i.e.* small work may or may not be blocked up, but wide surfaces are frequently supported with suitable local packings or jacks, in case any movement should occur through coarse feeds or too deep a cut. Taper work, in quantities of similar pieces, may be suitably gripped in pairs by reversing them, such as cotters for connecting-rods, and similar work. Another method is to interpose a wedge specifically kept for the purpose, and which is fitted by dowel pins into the face of the jaw. A piece of metal with a semicircular surface answers a similar purpose. To obviate the use of supplementary pieces, the vice is sometimes made with a swivelling loose jaw, in which case any irregular-shaped work can be secured. In this type it is customary to adapt the swivelling jaw approximately to the work, and then put a tension on the holding-down nut for fear that the jaw may lift from the surface of the vice and thereby make the work more or less insecure. Actually, the tension on the swivelling jaw when once properly adjusted should need no further attention, because the more frequently the nut is released and secured, the more it will wear and become defective. In the Taylors' vice, the loose jaw is held in place by means of a wedge fitting in a Vee notch on the face where the jaw slides. This carries a set screw, which arrangement gives a powerful grip to the work, and has a distinct advantage, since the pressure can be considerably increased and the wedge may be adjusted so as to instantly close the jaw on the work, whatever the width of opening may be required, of course within the capacity of the vice proper.

NOTES ON JIGS, THEIR DESIGN, CONSTRUCTION, AND USE

A jig is a holding device or a fixture which may be employed at the drilling machine, or used to hold special work while it is milled, turned, pressed, or ground, etc. A simple jig for drilling may be made from a cast-iron or steel plate having holes accurately located; the jig is then simply attached to the upper surface of the work and the drills passed through the holes in the jig plate, Fig. 7. A decided improvement is effected by making a true plate, and then after drilling inserting bushings of hardened steel. The accuracy of the bushes is obtained by grinding their internal and external surfaces concentrically. A good deal depends upon the quality of the work required and the number of pieces to be drilled as to kind of jig to be made. The jigs are designed in the drawing office, and in large works a special department with experienced men are engaged. It is imperative that a designer of jigs should be a man fully trained in the machine tool shops and is also versed in the possibilities of cutting tools generally. He should be able to decide before commencing his design which of the processes will give the best results, also the sequence of operations, as the work passes through the shops. This man is a specialist, not necessarily a first rank draughtsman, but a man who has passed through the various stages of tool room work, and thus able to make a happy combination of accuracy and utility in his designing with a view to simplicity and ease in handling the jigs when made. Jigs for interchangeable work should be dust proof, *i.e.* having ample provision made for the chips to get away clear of the important surfaces. The work should rest on spots rather than on broad surfaces, and finally the placing, securing, tooling, and the removing of a piece of work should all be done with as little call for skill as is practicable. The primary aim is to get a great number of pieces tooled alike, true to gauge, with a remote possibility of error.

A very simple but effective appliance is given, Figs. 61 and 62. An angle plate is secured to the machine table for drilling the holes marked. A stout axle is secured to the angle plate forming a pivot or bearing for this irregular formed bracket to ride on. The axle at once locates the bracket in one direction, while the second part of the jig can be easily moved by the slide which guides two bolts in or out of position as desired. Fig. 61 shows the slide moved to the right, bringing the large bolt with its head beneath the extended arm of the bracket. While in this position four holes are properly located and drilled. Similarly the jig slide is moved to the left, so that the bracket is supported by the shorter bolt which then locates the correct position for two additional holes at the end of the bracket. By this arrangement bolts and clips are unnecessary, also the marking of the horizontal position of the work. Therefore, for works of repetition, the brackets can be quickly located, drilled, and released. An interesting example of a more advanced type of jig is illustrated in Fig. 185, which is to show how a pair of end brackets or side frames can be precisely housed,

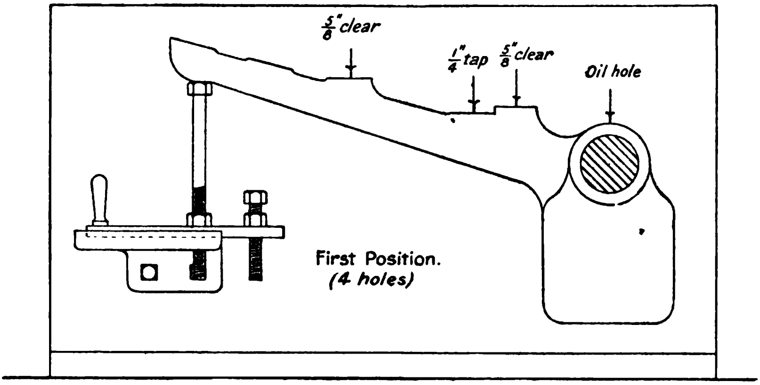


FIG. 61.—Holding and locating jig.

controlled and drilled, reamed, faced, and finished ready for the various spindles to fit in their respective places, all without trial or need of subsequent correction. To effect this result, the true fitting of the jig plate with its bushings and cutting tools are in perfect condition to commence with, and this accuracy must be maintained by very frequently gauging the parts concerned. Any slight deviation would reduce the precise finish of the product, so that duplicate tools are kept up to standard, ready for immediate use when necessary. The drills and reamers are carried by special sockets all of one diameter, quite regardless of the holes to be drilled and reamed, hence there is no necessity to change the bushings since they are all of an equal bore. The cutting edges not colliding with the hard walls of the bushings are in consequence long lived, and moreover the tools are more evenly guided to their respective cutting.

An excellent example illustrating the usefulness of a drilling and boring jig is given in Fig. 63. The jig is shown to be fixed on the bed of a Muir horizontal boring machine, provided with a powerful sliding head and a suitable table to receive the jig and the tools and fitments belonging to it.

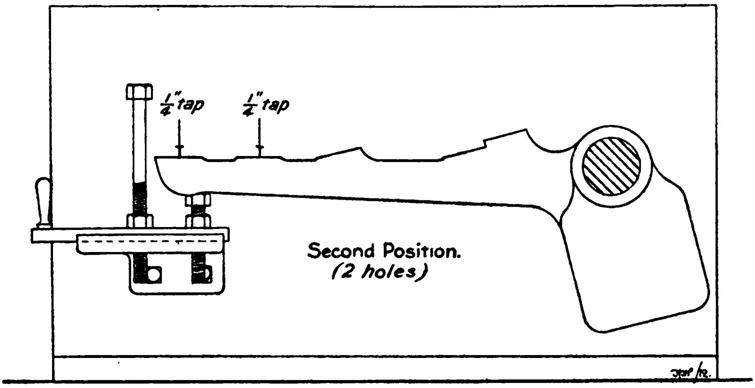


FIG. 62.—Holding and locating jig.

As the jig is now arranged it will be seen that the boring bar is housed in the end brackets, which are bushed to receive it, the holes being bored through the casting longitudinally. It will be noticed that one side of the jig hinges down so as to enable the work to be placed in position and taken out after it is finished.

After boring the longitudinal holes, the jig is released and turned at right angles for boring the cross holes. The example is from the Works of Alfred Herbert, Ltd., and shows the feed apron of their No. 8 vertical milling machine within the jig. The various tools and gauges used on this work are shown on the table. Referring to the jig, this would be a costly piece to produce since there are numerous holes, each of which appears to be of a different size. The correct spacing, grinding and bushing equipment would in all take a considerable time to execute. It is, however, only in the initial cost that jigs can be considered costly.

When the number of pieces alike warrant the designing and construction of a jig, the comparative cost of production is little. Moreover the jig is an essential appliance wherever the system of interchangeability of parts in construction is adopted. Without the aid of a jig the above example would not only need to be most carefully set out, but the fixing, gauging, and tooling operations would be put in the hands of a highly skilled mechanic.

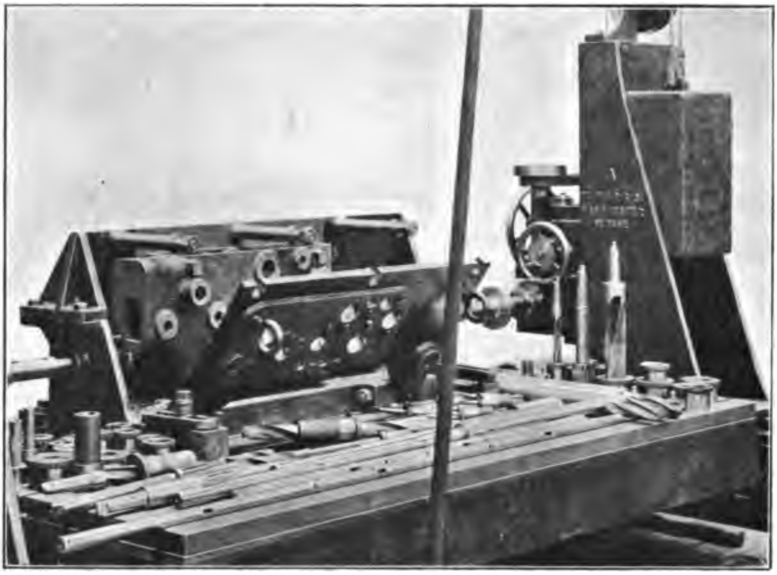


FIG. 63.—Hinged jig showing work, tools, and fitments.

Whereas in the case of Fig. 63, the work would be more quickly reproduced, by a less skilled workman, and all parts so produced would be alike in every respect without the care or need of measurement.

DRILLING MACHINES

Drilling Machines vary considerably in design, purpose, and power; those used for the smallest holes are usually made with balanced spindles, *i.e.* the spindle may be stationary at any part along its travel (Figs. 64, 65). There are, however, some exceptions, such as pillar drills, in which case the feed is entirely by hand lever. The intermediate sizes are provided with automatic or hand feed by worm and wheel gear, but these are generally made without the quick rise to the spindle. Modern machines of the radial type have the detachable feed.

In such cases a long lever actuates the rise and fall of the spindle, and by this means the drill may be instantly adjusted to any depth of hole, and then the automatic feed engaged; similarly the auto feed being arrested the spindle may be instantly raised to any height within the capacity of the machine, *i.e.* the length of travel available. This arrangement for deep holes especially is labour saving, while for bar and cutter work it is most useful, the alignment of the spindle with the bar can be more readily found, and at the same time the friction of the bar in its bearings can be judged and felt precisely.

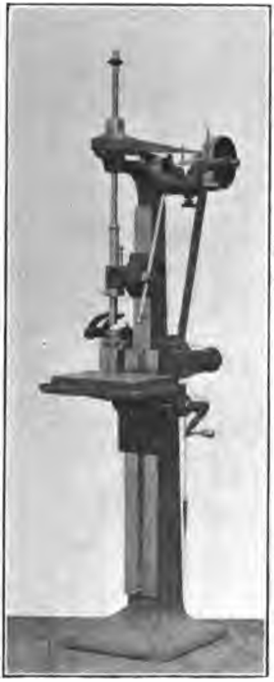


FIG. 64.—Sensitive drilling machine.

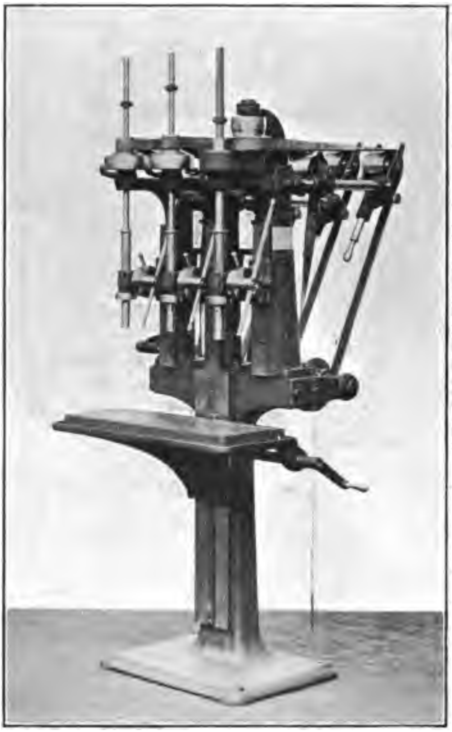


FIG. 65.—High-speed sensitive drilling machine with three spindles.

In vertical boring there is always a danger of the bar seizing owing to the cuttings heating up the bar or the dust accumulating around it as the bar descends below the work, but immediately above the bearing a leather washer may be fitted, and above this a piece of waste tied on fast to the bar; a good coating of oil on the waste serves to lubricate the bar during its descent into its bearing and so prevent the seizing referred to.

The test of a drilling machine for accurate work is decided by the truth and alignment of its bored holes, by the truth and good fitting of the spindle in its bearings, and the position of the table upon which the work is to be secured.

The drilling machine spindles fitted with automatic down feed are distinct from those which are known as sensitive drilling machines. The resistance to the power of the cutting tool, or the thrust, is generally taken up by hardened steel collars. In the best machines a collar is pegged on to each end of the feed screw-socket and one of a similar diameter pegged on the shoulder of the main spindle. Before the socket is inserted a loose collar is slid on, also one is placed on after the socket, the whole being kept in place by a pair of lock-nuts at the extreme end of the spindle. By having each face truly ground, the collars when at work considerably reduce the friction of the most vital parts of the machine. The loose collars are an important factor in the arrangement. It has, however, been found that this device is

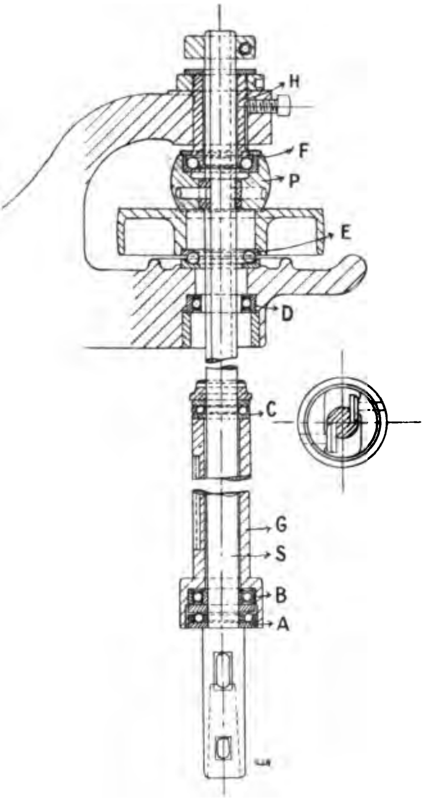


FIG. 66.—Sensitive drill-press spindle on ball bearings.

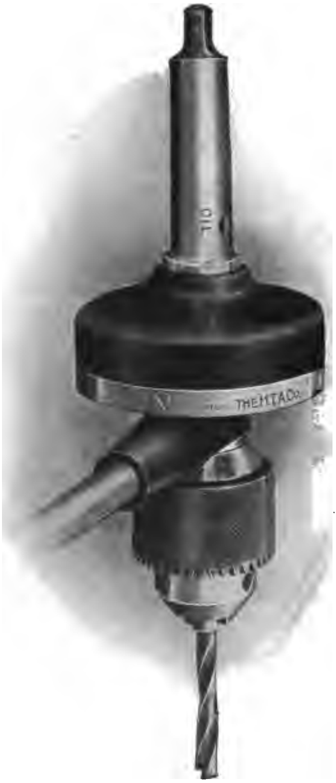


FIG. 67.—High-speed attachment.

inadequate for the high speed steel. Drills made from this material could not be worked to their proper capacity, therefore ball bearings have been substituted for the hardened collars. Where the free use of ball bearings has been adopted a proportionate increase in the efficiency of the machine has resulted.

Fig. 66 shows one of the latest types of this; the illustration represents Rice's patent as made by Messrs. Smith and Coventry. It will be seen that the main spindle is relieved of all friction by a universal system of ball bearings. The distribution of the six pairs of bearings and the introduction of two roller keys have effected a marked improvement. As the spindle is traversed up and down, the roller keys engage with it and rotate it. The driving pulley P is supported at its upper and lower ends by bearings E and F. The sleeve H is adjustable, so that P may be placed in or out of position.

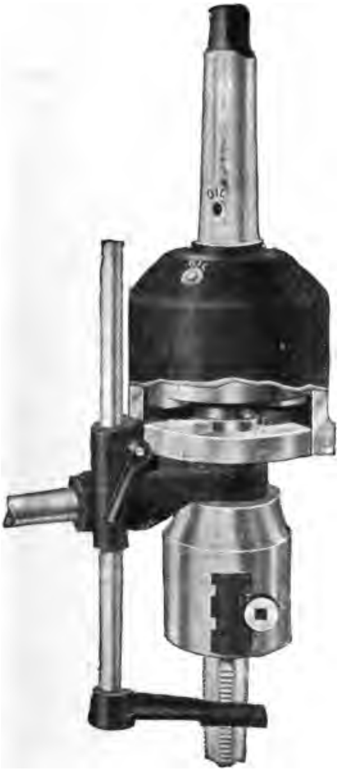


FIG. 67A.—High-speed tapper.

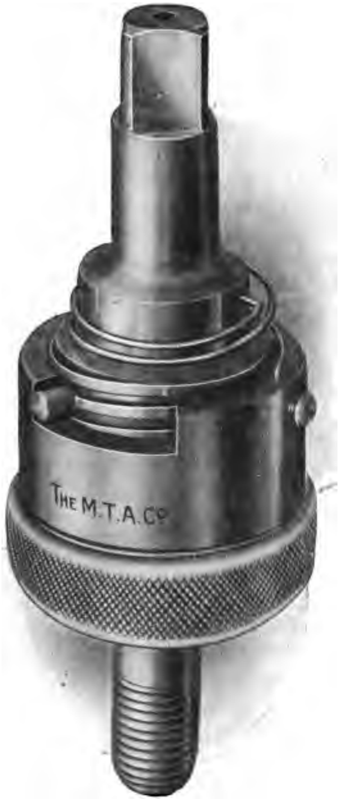


FIG. 67B.—High-speed studder.

The feed sleeve G is provided with a rack and contains the ball bearings A to receive the thrust and B to guide the spindle S concentrically with the sleeve G, the pulley P being so arranged as to give no pull whatever on the spindle.

In addition there are jockey or guide pulleys directing and controlling the path of the belt, these together with the bracket carrying the driving pulley are also fitted with ball bearings.

With this anti-friction drive it is claimed that, owing to the sensitiveness and consequent rapidity with which the drill can be handled, the wider arrangement of speed and immunity from seizing, a production varying from 200 to 400 per cent. above the ordinary drill presses is obtained. The speeds are very high, viz. counter-shaft 800, spindle speeds 600, 900, 1350, and 2025, thus with a main spindle of only $\frac{7}{8}$ in. diameter, and a $1\frac{1}{2}$-in. belt running on a 6-in. pulley, a 1-in. twist drill can be put through a bar of metal at a high speed without any gearing. Appended are lists of the sizes of Whitworth standard drills in ordinary use, also one showing the sizes of drills for the British Association screw threads, together with corresponding sizes of the drills suitable for tapping in each case. Students and apprentices should familiarise themselves with the tables, so that whether the work to be done is large, medium, or small, they will be intelligently able to mark out their own work, and, if necessary, fix the drills and tap such holes as are required. (See also Fig. 135.)

For geared machines there are high-speed attachments which may be used when drilling small holes. The increased speed is usually at a ratio of three to one. One of these is shown in the sketch, Fig. 67. In 67A and 67B an attachment is given for tapping a drilled hole and inserting a stud. The arrangement has a safety device to protect the tap. In the latter view the stud is carried in the chuck, by this arrangement a cylinder may be drilled-tapped and studs inserted without removing the casting from the table.

HIGH-SPEED "NOVO" DRILLS, TAPPING SIZES, WITH TAPER SHANK.

Diameter of tap.	Diameter of drills.	Length of drills.	Diameter of tap.	Diameter of drills.	Length of drills.
Inch.		Inch.	Inch.		Inch.
$\frac{1}{4}$	3 w g	6	1	$21\frac{1}{2}$ } m/m	$10\frac{1}{2}$
$\frac{5}{16}$	$\frac{1}{4}$	$6\frac{1}{8}$	$1\frac{1}{8}$	24	$10\frac{3}{4}$
$\frac{3}{8}$	$\frac{5}{16}$	$6\frac{3}{8}$	$1\frac{1}{4}$	$27\frac{1}{2}$	$11\frac{1}{2}$
$\frac{7}{16}$	$\frac{23}{64}$	$6\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{11}{64}$	12
$\frac{1}{2}$	$10\frac{1}{2}$ m/m	7	$1\frac{1}{2}$	33 } m/m	$14\frac{1}{4}$
$\frac{9}{16}$	$\frac{15}{32}$	$7\frac{1}{2}$	$1\frac{5}{8}$	35	$14\frac{1}{2}$
$\frac{5}{8}$	$13\frac{1}{2}$ } m/m	8	$1\frac{3}{4}$	$1\frac{1}{2}$	15
$\frac{11}{16}$	15	$8\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{19}{32}$	$15\frac{1}{4}$
$\frac{3}{4}$	$\frac{21}{32}$	9	2	$1\frac{23}{32}$	$15\frac{3}{4}$
$\frac{13}{16}$	$\frac{11}{16}$	$9\frac{1}{4}$	$2\frac{1}{8}$	47 m/m	$16\frac{3}{8}$
$\frac{7}{8}$	19 } m/m	$9\frac{3}{4}$	$2\frac{1}{4}$	$1\frac{15}{16}$	$16\frac{1}{2}$
$\frac{15}{16}$	$20\frac{1}{2}$	10	$2\frac{3}{8}$	$2\frac{1}{16}$	17
			$2\frac{1}{2}$	$2\frac{3}{16}$	17

"SETTING OUT"—MAIN CASTING OR BODY FOR DRILLING MACHINE

Another form of drilling machine is shown in Figs. 68, 69. The body casting is detached and is self-contained, since it carries the machine spindle and the horizontal driving shaft respectively. The chief points of importance in marking out the casting, as in the subsequent tooling, are the alignment of the holes AA with the holes BB, both of which decide the position of the drill spindle, and in their

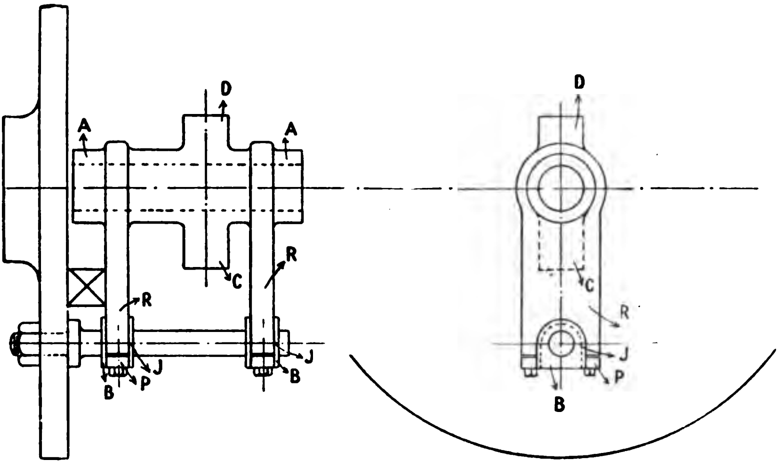


FIG. 68.—Bearings located on axle decide centre for shaft.

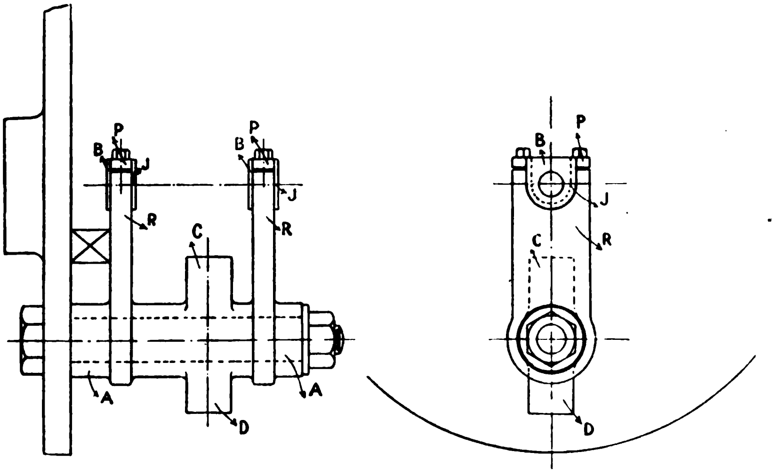


FIG. 69.—Boring drilling machine spindle bearings.

position relatively with the bearing CD, which carries the driving shaft. The bearings BB are adjustable or "split," bearings being each of phosphor bronze and let in the arms RR. The upper or cap bearing is kept in place by the plates or straps as shown at p. 51. At the outset, before any marking out is done, the brasses must be let in a stiff fit and properly secured with their respective straps.

In machines of the best class the brasses will be tooled over at the faces JJ and sweated (soldered) together, and machined so that they will readily "knock" into place with a blow on a bit of hard wood. The holes AA and BB are next plugged up and the casting overhauled. The bosses AA are supported on Vee blocks, as in Fig. 1, and a parallel strip or other suitable support given to the arms RR. While in this horizontal position, a line may be drawn around the body of the casting, passing approximately through the centre of AA and BB, also across the faces CD. The casting may now be given a quarter turn, thus bringing the marked lines into the vertical plane, the exact position being decided by a square, then a line intersecting the previous one will give us the true centre if the respective cores are correctly placed. It is most important to take a general survey of the conditions, there may be a little "give and take" necessary to bring the various bosses or cores into a satisfactory position, but the axis of the shaft and spindle must be precisely intersected by the lines BB, passing through the bosses C and D. Any error in this particular would disturb the correct running of the bevel gears, one of which rides on the driving shaft D, and the other on the drill spindle S. When satisfactory the various holes are marked out and the circles dotted with a fine punch. There are several ways of holding and tooling the body casting.

The boss A may be held in a jaw-chuck, but to guide and properly control the casting axially in the lathe the opposite end A_1 must be turned to fit a stay and run smoothly in it.

This is a good plan enough where the parts to be bored are all that must be considered, but a slight movement or dip of the casting in the stay will materially alter the position of the previously marked centres of the spindle bearings BB and of the horizontal shaft bearings CD respectively. To maintain the correct alignment attention must be given to the stay, especially to note the height of the work, *i.e.* to gauge its precise distance above the bed, this height may be kept by a scribing block, and as occasion requires it the position may be verified. A three-point metal stay has largely taken the place of the one having wood dies, but where the latter must be used the above remarks apply.

In the sketch, Figs. 68, 69, the bracket is shown to be bored in the main holes AA, and fixed on a shaft set at a predetermined distance from the centre of the spindle. The shaft is guided to its place by previously making a very fine line on the face plate, and afterwards verified by means of a surface gauge, and a good steel rule, or a specially prepared gauge. When large quantities of pieces are thus to be bored, a special mark or circle can be made on the face plate within which the diameter of the holding shaft can be readily located.

Referring again to the holding of the casting, an alternate method is to secure the work to an angle plate, in this arrangement the use of the try square is frequent, also a small scribing block will show when the original line round the body is at a precisely uniform height from the horizontal face of the angle plate.

SETTING AND TOOLING DRILLING MACHINE. BODY CASTING

In the best classes of machines the holes AA may be plugged and the bosses turned to gauge diameter. This method provides means for a special form of angle plate, in which case cap and block bearings will be cast on the upper surface, then bored and faced at right angles to the lathe plate. Such a contrivance is called a lathe jig, and everything else being equal the boring could be satisfactorily accomplished at the radial-drilling machine, which for such work should be called a boring machine. A somewhat similar example appears in Fig. 103, which represents the boring of a headstock, the bar essentially taking a bearing beneath the work, double-ended cutters are used. It is customary to use a boring-bar at the lathe, having a slot to receive the cutter very near the end, this answers satisfactorily when the hole to be bored is shallow, but deep holes have to be tooled very carefully or the bar may shift as it journeys through the roughly-cored hole. Generally the vibration set up demands a slow feed, but the cutter should always be large enough to tool up the surface clean, however eccentric or bent the hole may be. When this is not possible much less depth of cut must be taken, since the cutter will be opèrating unequally and at some points entirely on one side. The bar will be forced or sprung out of a straight path; the deeper the hole, and the more eccentric it is, the greater the strain on the bar and the tool box in which it is supported.

It will be obvious that by supporting the above body casting in the manner shown there can be no possibility of error in the parallelism of the respective bearings, besides this the actual distance between the centres of the bores will be the same for any number. In this connexion reference may be made to Fig. 70, p. 54, showing how an actual test may be obtained of a drilling-machine spindle relative to the truth of the table upon which the work is supported.

The circular table has a bearing in the bracket attached to the column or pillar, and if correctly machined it should lie perfectly square with the spindle at any point. This may be ascertained by securing a thin rod in the parallel drill socket, the rod being bent at right angles and again bent downwards for a short distance, the extremity of the wire rod being pointed. For a Morse taper as shown (Fig. 67) the spindle should first be raised a little then gradually lowered until the wire will just hold down a piece of writing paper on the surface of the table. If the writing paper is held with an equal tension at any point as the spindle is rotated, then we may say that the spindle bearings are in perfect alignment with those carrying the table. This is a severe test, but one which must be made to see that the table is correctly placed. To obtain precise alignment of the spindle bearing with that of the table bearing it is undoubtedly the safest plan to bore out all these holes at one setting, in which case the pillar carrying the bracket must be machined first. The work is generally done at a horizontal boring machine, but if it is decided to bore the table bearing in place by the machine's own spindle, then a supplementary bearing beneath the hole

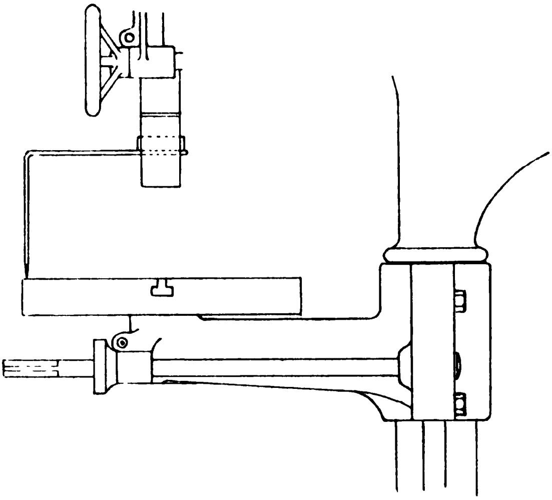


FIG. 70.—Testing truth of drilling machine table.

to be bored must be rigged up on the base plate just to support the bar and hold it rigid while the cutters are operating. It will be obvious that both the methods recommended are more likely to give satisfactory results than that of doing the boring while the parts are detached, owing to there being two settings of the parts in the latter case compared with one setting in the former.

UNGEARED DRILLING MACHINE WITH SPEED REGULATOR

In this machine, illustrated in Fig. 71, an arrangement is fitted to give the driving spindle a variable speed.

The device is really the taper-cone drive, so fixed as to be within easy reach of the operative, and by a slight movement the speed may be accelerated or diminished as required within the capacity of the drums D and S.

The regulating device consists of a loose belt O which encircles the taper drum D. When the operative desires to change the speed of rotation, the endless belt O is moved along the conical pulley or drum, the movement being made through a forked arm U which guides the path of the belt. The arm U may be adjusted to any position along the slide W until the pointer I indicates the speed on the speed table R, when thus adjusted the slide may be locked.

To obtain a uniform pressure on the endless band between the speed drums D and S, the bearings of the upright shaft D are made to slide in parallel guides as is shown clearly at X in the enlarged view.

Now the connecting rod A controls the movement of both sliding blocks by the two screws Y and the handle B. A very slight change of position of the handle causes the screw threads to advance the parallel block bearings and thereby put a grip or tension on the endless belt U.

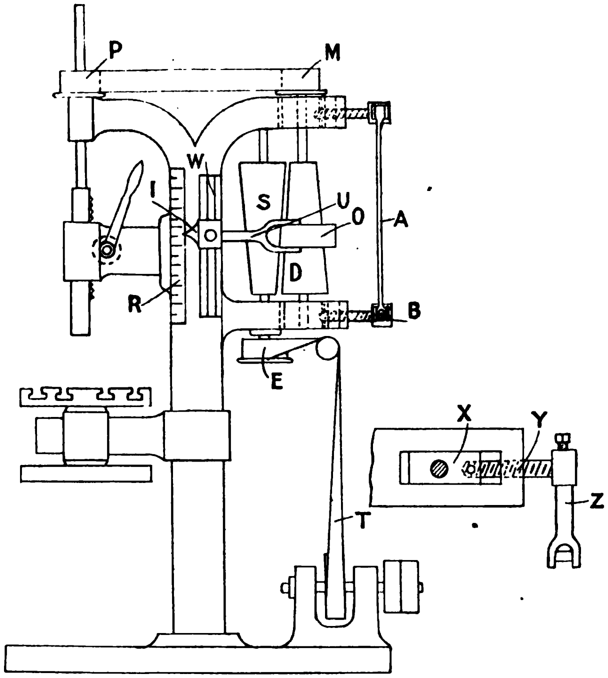


FIG. 71.—Drilling machine with self-regulating drive.

On the base of the cone shaft S a pulley E is keyed which is rotated by the driving belt T, similarly at the top of the cone shaft M a belt communicates with the pulley on the drilling spindle at P, thus giving it rotation.

NOTES ON CRANK SHAFTS

Crank shafts are now almost entirely made from mild steel. They may be forged into shape and welded or they may be specially cast in moulds. Very small cranks are forged easily by the stamping hammer, but some larger ones are forged and bent into the required shape. All the above are made from bars of round section. The advantages of this form of crank shaft are twofold. Firstly, there is no cutting to shape necessary. Secondly, the fibre of the material is unbroken during the bending processes. These bent cranks are made from the smallest sizes up to shafts of 6 in. diameter.

Locomotive engine and other engine crank shafts are generally forged down and cut out from flat slabs of mild steel. The rectangular webs are formed by punching two holes and then cutting out a solid block between them. The block may also be sawn or slotted out between drilled holes, and the crank roughly formed in a special machine which is provided with a large revolving disc, on the rim of which a number of cutting tools are secured. The cranks are then ready for turning and finishing in the lathe.

Small crank shafts which are forged into shape are conveniently formed between the upper and lower dies of a stamping hammer. In this case it is obvious that every crank will be true to dimensions, thus reducing the setting out and the subsequent tooling to a minimum.

Crank shafts for treadle lathes have both cranks on one side of the centre, this renders it imperative that the setting should be precise, as there is but a very small margin allowed for the latheman. Short bends are removed with a cramp and links; longer bends can generally be got out by using a bar, *i.e.* a fulcrum is put on the bed beneath the shaft and the bend is removed by springing with a steel bar. Hand, and the smaller sized forged cranks may have irregularities too great to be got rid of by cold treatment; in such cases it is generally sufficient if the parts are first heated "black hot." If the cranked parts are to be corrected, a twisting wrench can be used to advantage, whilst the shaft is placed horizontally in a strong vice. A long straight-edge and two parallel strips may be used to gauge the results during this process of straightening. The parallels are placed on the crank portions, and thus gauged for alignment.

OVERHUNG CRANKS

Cranks of the overhung type may be forged from mild steel or wrought iron, and for some purposes cast-iron cranks are used, but their dimensions are considerably increased. Before marking out those of mild steel and wrought iron it is generally the practice to surface the back and faces first. There are several points of advantage in this, the piece can be clamped to an angle plate, and thus lined out to a templet or set out from the drawing without any packing or other support being required.

After the bore for the shaft and the crank pin have been located and "centre popped," the crank-slab can be secured on parallel strips to the table of a boring machine or radial drilling machine, and both holes can be tooled at one setting of the work. Then, since both boss faces have been tooled, the cutters can be much more easily set to work, than is the case when the face is not lying at right angles to the cutter-bar. Especially is this to be seen when one or only a small number of similar cranks are to be tooled and the cutters and bar have to be changed for each. To bore out the hole for the crank-pin would need specially formed tools, and possibly a taper reamer for finishing the hole. Such a job is more suited to the lathe. There with a a swivelling motion to the slide rest, the hole can be tooled to the correct taper without a reamer. In using a bar and cutter at the drilling machine a support should be provided beneath the work for the bar to ride through. This greatly assists the progress of the cutters, and if some similar support could be used at the lathe, the rate of traverse might be considerably increased. In special boring lathes the hollow spindle forms a housing for the various bars when carried in a turret at the opposite end. Each bar being fitted with its respective cutter, no alteration is necessary for work of a duplicate character.

PORTABLE CRANK PIN TRUING MACHINE

A portable appliance for truing up a crank pin in place is given in

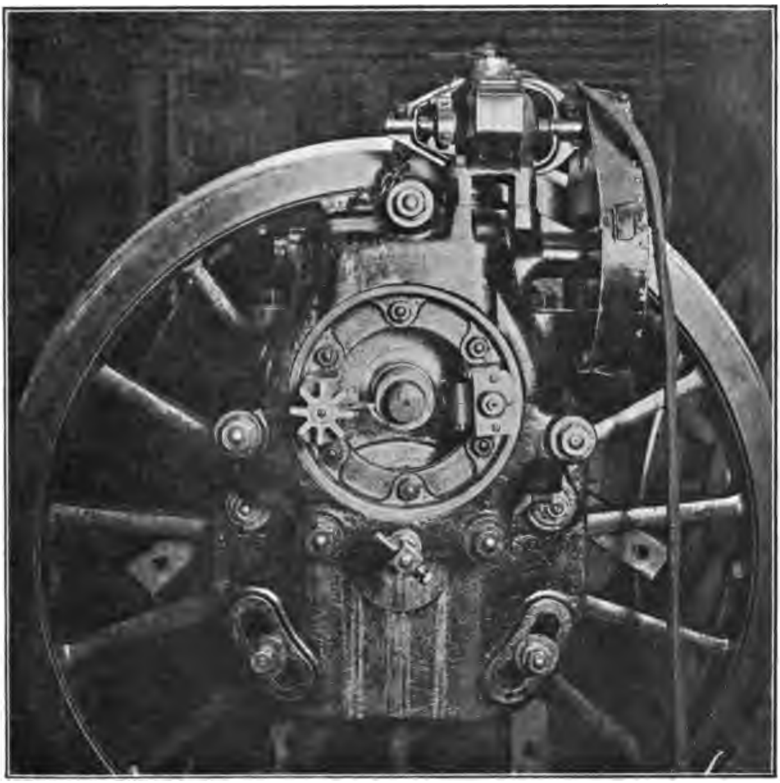


FIG. 72.—Crank pin turning machine.

Figs. 72, 73. The apparatus which is a self-contained mechanism, motor driven, may be rigidly secured to the driving wheel of a locomotive engine, and correctly adjusted from the axle-centre. It

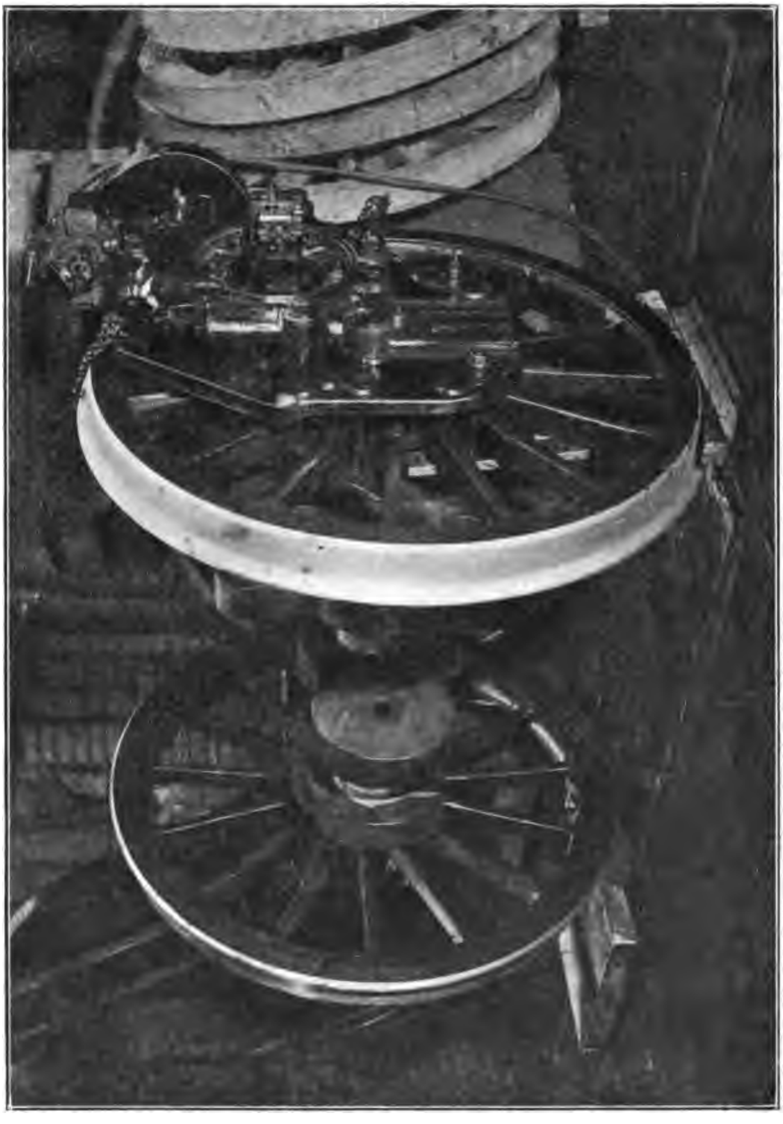


FIG. 73.—Crank pin turning machine.

will be noticed that a small turning tool is fitted in a holder, which is carried in a slide. This being fed by the star wheel takes a skimming cut, thus restoring the worn or irregular parts of the pin back to truth.

The view shown in Fig. 73 makes it clear that the apparatus has been brought and attached to a driving wheel, while the pair are simply wedged to stand erect. The crank axle being undisturbed by this arrangement a great saving of time is effected.

A system of reducing gear is employed to give the tool a suitable speed, for in this case the turning tool revolves about the axis of the crank pin. This is an ingenious arrangement, devised to overcome a somewhat laborious and troublesome task. There are two or three other points worthy of note. The true centre of the engine driving wheel is indicated by the projecting pin shown in Fig. 72, this being the key to the mechanism, from this centre a gauge may be used to locate the position of or verify the centre of the crank pin, *i.e.* the actual distance of the throw. This enables the fixture to be located precisely on the driving wheel. A further point is that of moving the cutting tool in a straight line along the surface of the pin; to effect this the tool slide must act similarly to a lathe slide rest, therefore it is obvious, to obtain a satisfactory result on the surface of the crank pin, it must be carefully set. It may be asked how is it that a truly turned pin, made of a reliable quality of steel, should wear away so unevenly as to need re-turning up. Is it in any way the fault of the steel? The answer is in the negative; the reason is that the pin has more work to do at one point than another. It is unlike a shaft revolving in a bearing where the pull is practically uniform, in the above case there is a pushing and a pulling, as well as a revolving movement of the pin, and this acting at a very rapid rate.

It may be stated that whenever a reciprocating motion is converted into a rotary one the wear on the parts will be found unequal, producing an irregular dimension. Referring again to the form of the crank, both on the pin and in the journal bearings, it will be noticed that a decided curve is left in the corners; these greatly strengthen the shaft, rendering it less liable to fracture (see Fig. 76). After repeated trials of steel shafts made in the above manner, very satisfactory results have been obtained, so that comparatively few shafts are now forged in wrought iron.

SETTING OUT, SECURING AND TOOLING A SOLID CRANK SHAFT

In Fig. 74 a steel crank shaft is shown supported on the marking-out table, while the centres for the throws are set in position. It will be seen that a stout crank block, which carries the centres for the throws, is fitted at each end of the shaft. Great care is given to obtain a correct setting of the blocks, since the turning and subsequent adjustment and alignment of the motions are dependent upon this accuracy. At the near end the block is levelled to a straight-edge, and is further verified by the aid of a scribing block shown. On the surface of the second throw stands a plumb square, used to approximately set that part parallel with the straight-edge; this position having been obtained by the use of the small screw jack shown. It should be noted that the packing or supporting blocks are as few as is possible consistent with the weight and shape of the object to be marked off. The second crank block is at right angles, the true position being obtained by means of the L square shown. On a line with the centre for the throws two arms extend from each crank block. These embrace the cranks, and being provided with set-screws for adjustment, give additional support to the centre. In "sweeping the throws," reference is made to Fig. 75, which clearly illustrates a crank-turning lathe in operation. Since the weight of the shaft, blocks, and throws, being on one side of the centre, is considerable, a heavy balance weight is necessary to balance them. This is clearly shown in the figure. A further noticeable point is the rod housed between the crank block and the web; the rod being fixed centrally with the crank pin under operation gives a decided check to the thrust inwards, caused by the springing of the block through the compression, or pressure exerted on the loose-head poppet centre. The tool rest is essentially a very narrow one, so that the cutting tool may be traversed parallel across the bearing as far as possible without interference.

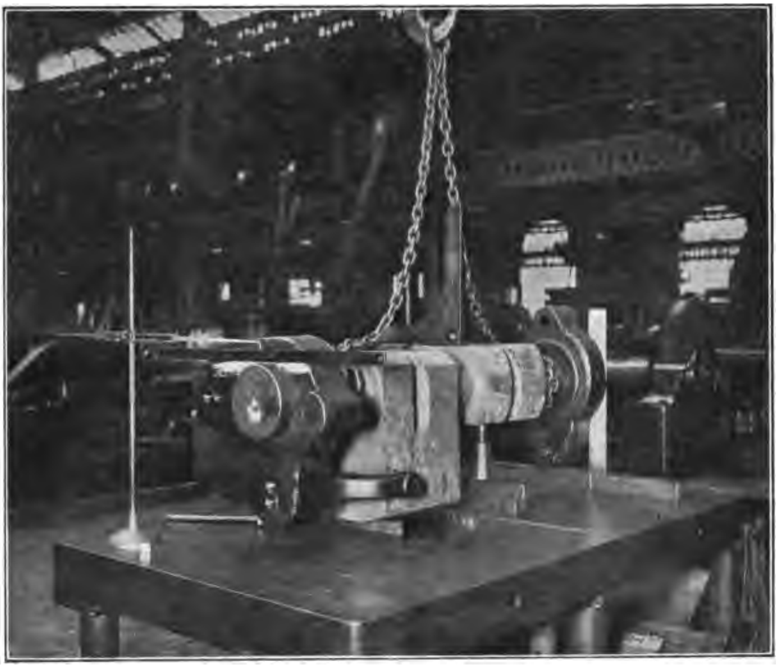


FIG. 74.—Setting out centres of engine crank shaft (L. & N.W. Ry. Co., Crewe).

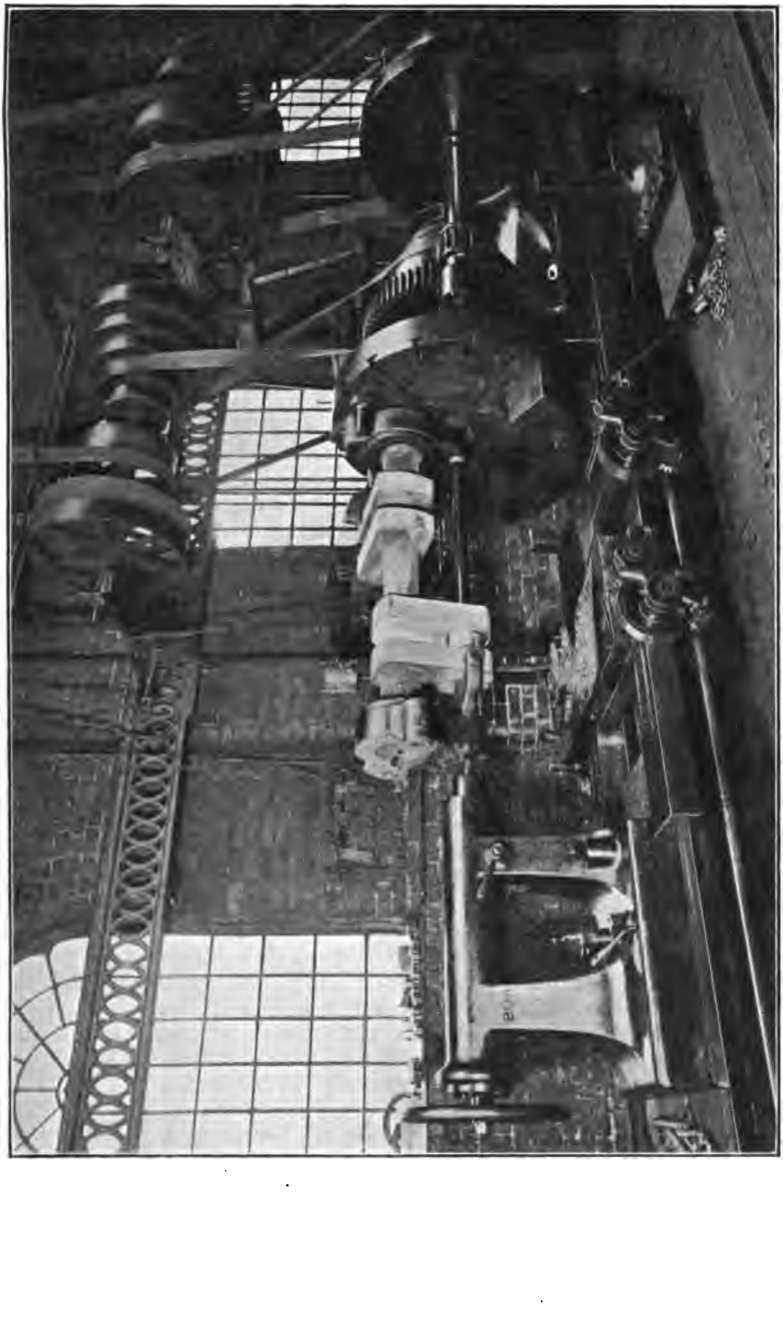


FIG. 75.—Crank turning lathe sweeping the throws.

LOCOMOTIVE ENGINE CRANKS

An illustration of a built-up crank shaft is given in Fig. 76. The shaft is supported in its journals by Vee blocks and parallels. The cranks are shown to be balanced by the extended slabs, one pair of which is vertical in the figure. To gauge the true alignment of the crank on the marking-off table, while the keyways are lined out, a special device is employed. On the near side, and secured between the slabs is a disc, the diameter of which coincides with that of the crank pin, these together form a support to a straight-edge. A scribing block is also shown, gauging the horizontal position of the straight-edge, while a square is used to verify the truth of the setting; the latter being shown at the right. By the use of this device it will be understood that although the slabs are comparatively close together, a line may be marked precisely in the right place.

MOUNTING A CRANK FOR TURNING

To produce a crank shaft true in the throw and also on the parallel and bearing portions of the shaft will require great care in the mounting, or fixing, and in the arrangement of the crank blocks, and method of driving them. The uniform balance of the work in the lathe is the first consideration. A crank when properly driven should not spring on to or away from the cutting tool, it therefore follows that the heavy parts requiring the most tooling should be roughed out first. The usual practice is to drill, saw, slot, or mill out the block on the slab crank, and in the case of solid forged shafts for locomotive engines, to further get away a considerable portion of the metal by securing the shaft to a special milling machine which is provided with a very stout disc, carrying say 100 cutting tools.

The disc opens the way between the crank sides or webs and also cuts the crank pin, forming it from a square block into a roughly turned round one. To effect this the machine cradles the crank and swings it radially towards the revolving cutters, a transverse feed is given automatically. This greatly assists the turning tools, and as the shaft is free at the ends the stresses can get away freely. When placed between the lathe centres a special block carrying the centres for the throws is secured. This arrangement is shown in Fig. 74, while the crank axle is on the table, also in Fig. 77, which illustrates the crank throws being turned in the lathe. The cutting tools necessarily must be fixed at a considerable distance from the lathe rest, this overhang is generally supported by a bolt, the head being reduced or one of Tee-section is placed between the ways of the transverse slide and the under side of the turning tool. In cases where the neck of the crank is narrow, the tools are drawn out thin so that as much cutting as possible may be done at one operation. Very narrow necks are turned by stages, the central part first, and afterwards the right and left hand sides.

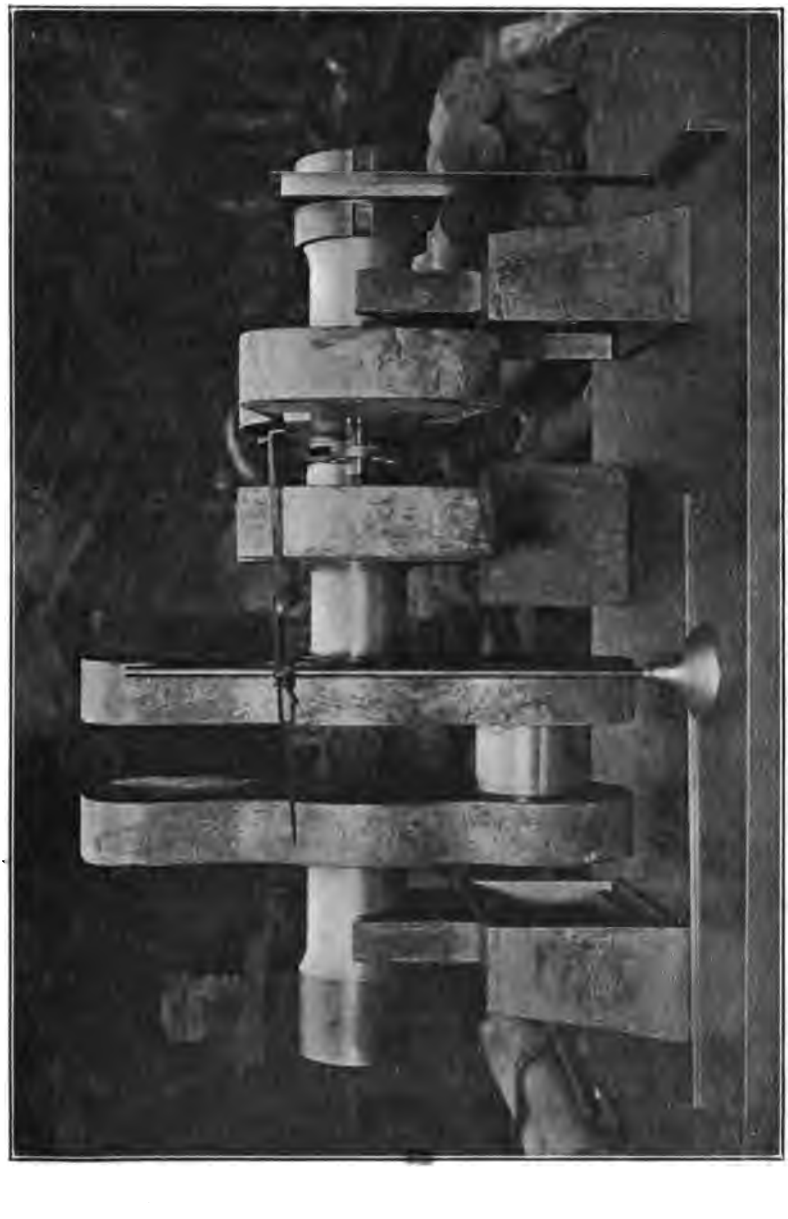


FIG. 76.—Marking the keyways on built crank.

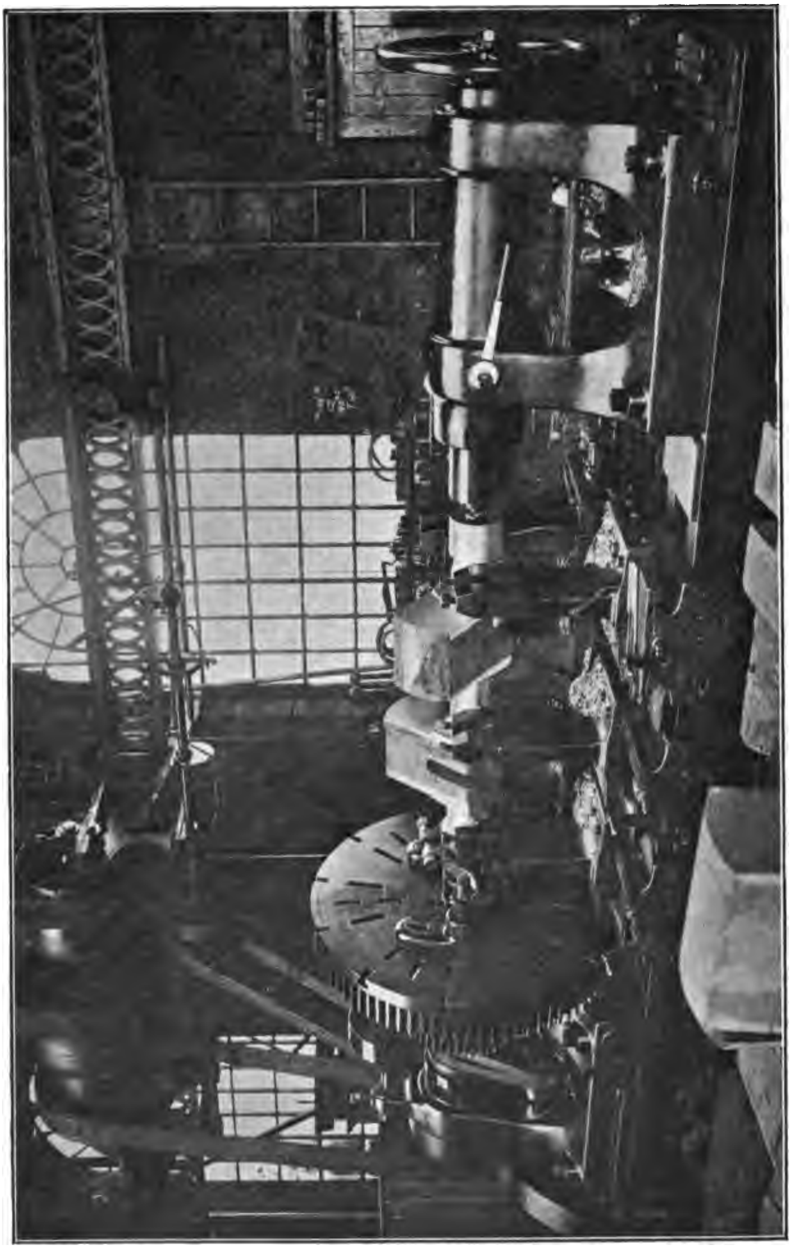


FIG. 77.—Crank turning lathe, roughing out.

CRANK TURNING LATHE

A crank turning lathe is given in Fig. 77. The lathe is of a special design, carrying three distinct saddles, each being fitted with two tool rests. By this arrangement six cutting tools are capable of operating on a crank shaft at the same time. It will be seen that the tools are reducing the parallel portions and the journal bearings, the finishing being left to a later stage. It should be noted that the driving clips are attacked on each side with an adjustable driver, so that the force exerted will be equal on each side of the centres. This duplex driving is the only correct way of obtaining truly turned work when secured between two centres, especially when subjected to heavy cutting. Although very small work is frequently produced with one driver, the principle should be double driving: see the "Clements" driver (Fig. 139).

For these photographs I am indebted to the Chief Engineer (J. B. Cooke, Esq.) of the L. & N. W. Railway, Crewe.

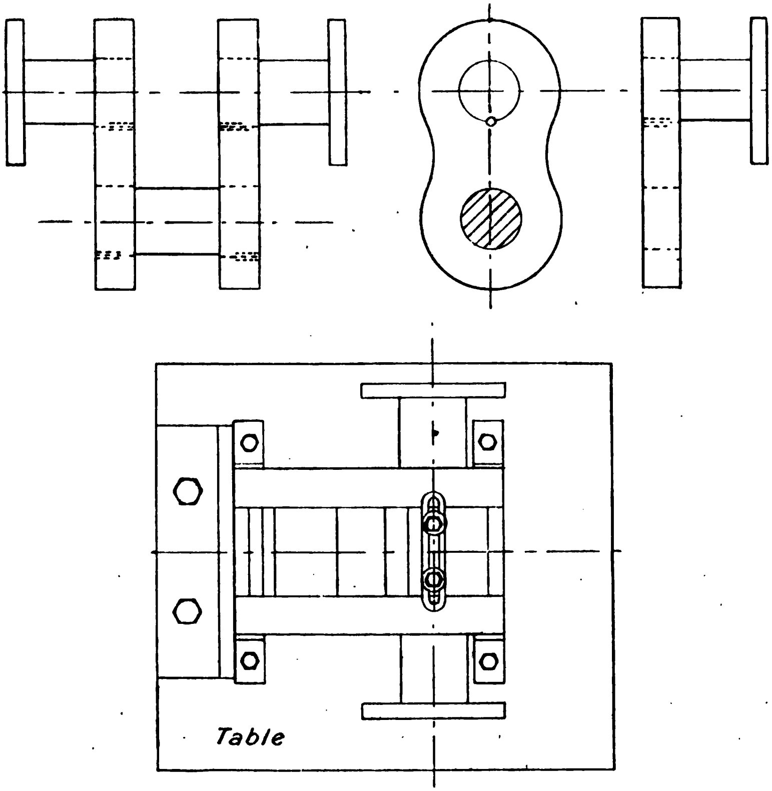


FIG. 77A.—Building up a marine crank shaft.

BUILT UP CRANK SHAFTS

There are certain advantages in favour of building up crank shafts. The several pieces can be set out, secured, and tooled much more easily than is the case with solid forgings. The forgings for the crank webs are marked out, planed, bored, and slotted, and the crank pins are turned and finished to the drawing. The pieces of shaft are next roughly turned, except on the parts fitting into the crank webs. These portions, like those of the crank pins, are left a little larger for shrinking into the bore of the webs. When this is done the webs are heated so that the shafts and crank-pins drop in an easy fit. A small collar or shoulder is turned on the shaft so that the piece when shrunk in will rest truly on it. The shoulder is turned off at the next tooling. After cooling down a hole is drilled half into the web and half into the shaft. Into this hole a turned pin is driven by means of a tup hammer. To

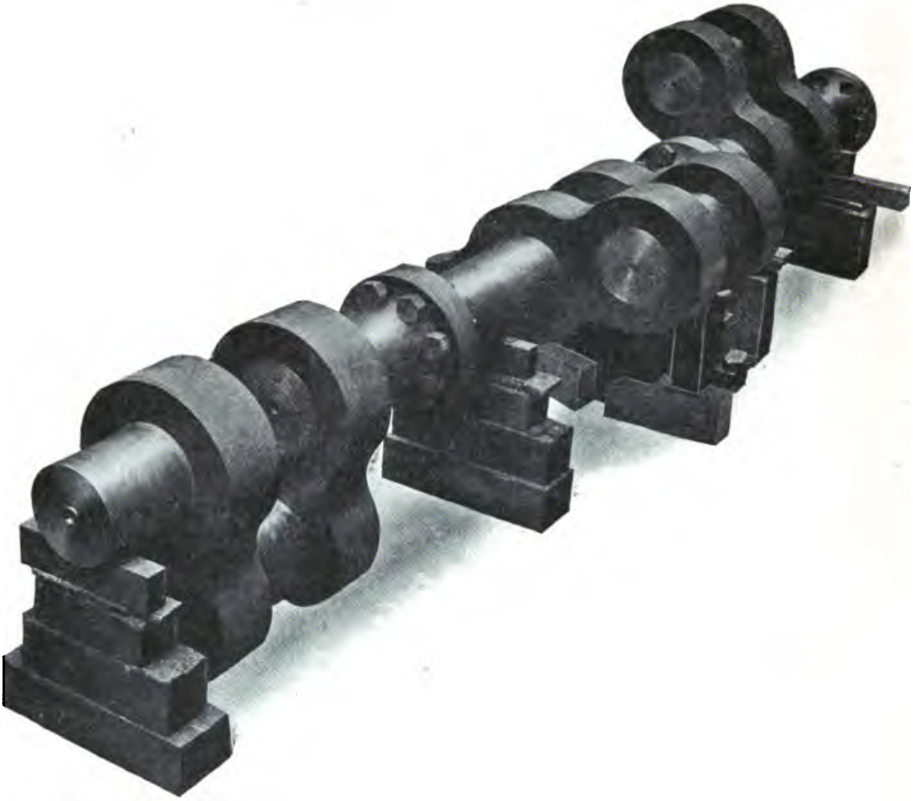


FIG. 78.—Marine engine crank shaft, 1 ft. 11 in. diameter, 35 ft. 6 in. long.

obtain a sound fit the webs are bored $\frac{1}{1000}$ of the diameter less than the diameter of the shaft.

Finally the crank pin is shrunk into place. To effect this the two webs are bolted on a horizontal table with their ends butting hard against a vertical end of the table formed by fixing a stout angle plate. A pair of parallel blocks are placed between the webs to keep them parallel and at the right distance apart (Fig. 77A). The webs are then heated and a pin driven in as before a very tight fit. After cooling the built-up crank is taken to the marking-out table and marked out. Any inaccuracy in the original centres will now be detected and, if necessary, the centres drawn until the shaft runs truly in the lathe. The dimensions are for a 12-in. shaft, pins $2\frac{1}{4}$ in. and $1\frac{1}{4}$ in. diameter respectively.

Photographs illustrating built-up crank shafts are also given in Figs. 78, 78A, these show the arrangement clearly, the diameter of the shaft in Fig. 78 is 1 ft. 11 in. and the length 35 ft. 6 in.

Two types are shown, one solid steel, the other hollow; the latter is usually made hollow by forging and afterwards by boring. The hollow shaft is the stronger, weights being equal. Great care is given to the erecting of the various parts, and a graduated wheel is shown on Fig. 78A which will verify the setting of the various throws.

The above examples serve to show the importance of marking out and tooling precisely to gauges, there is no subsequent correction admissible; this being so, the templets used in marking each piece and the gauges and

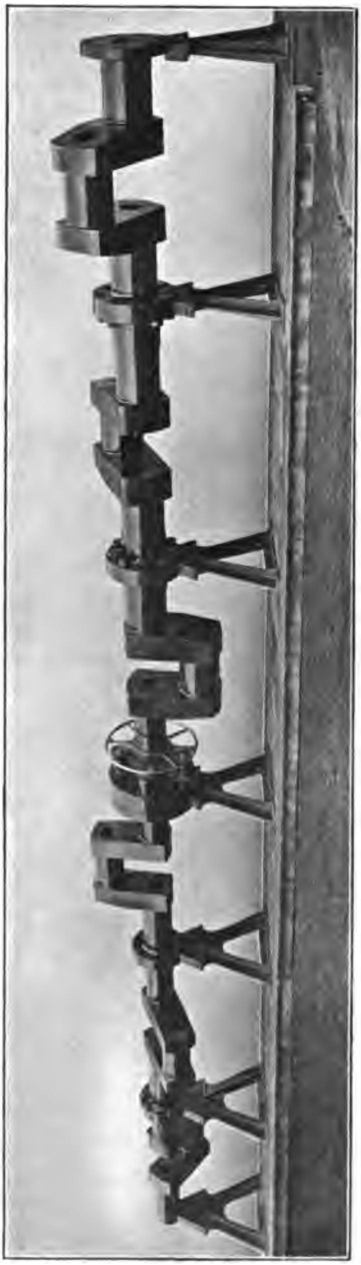


FIG. 78A.—Built-up crank shaft for marine engine.

tools for this work cannot be too accurately made and carefully used.

The material is the open hearth steel of a good quality. It is in work of this character that drilling and boring jigs are of the greatest advantage. Care has to be given to keep the cutting tools in good condition, so that heat generated will always be under control. To do this and assist the tools a copious stream of lubricating liquid is pumped automatically on the operating tools.

The fluid is used over and over again by means of pipes which conduct it back to the tanks.

THE GARDNER PATENT CRANK PIN TURNING MACHINE

Crank turning, owing to the lack of rigidity of the parts near the cutting tools, has always been a somewhat troublesome task, it being almost impossible to obviate entirely the tendency for the work to spring. This however has been overcome by the arrangement shown in Figs. 79, 79A, which illustrate Gardner's Patent Crank Turning Machine. The chief principle involved is the method of forming the crank pin by means of a cutting tool made the full width of the crank pin. Undoubtedly this method is rendered possible by having a positive drive, which, in this case, is as close to the crank pin as is practicable.

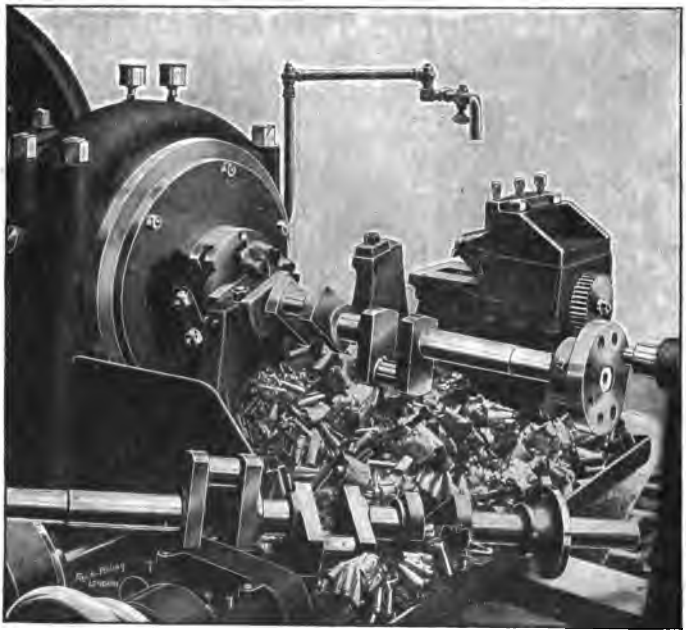


FIG. 79.—Gardner's crank pin turning machine.

Referring to the figure, it will be seen that the fast headstock spindle is of exceptionally large dimensions, having ample capacity for the crank to be housed securely inside, so that the crank shaft may be securely housed within it. On the near face of the spindle a special chuck is fixed, which instantly grips the crank, securing it to the correct throw. By thus being housed within the spindle and supported in the chuck close up to the web, which is fixed by clamping screws, the crank shaft is rigidly held on one side of the throw, while the overhanging end of the shaft is supported by the crank block and loose headstock in the usual way as shown.

The transverse slide carries a tool holder fitted with a roughing-out tool, and on the opposite side of the pin a second tool holder, carrying the finishing tool, is secured so that the turning operation can be completed without removing the crank or the tools.

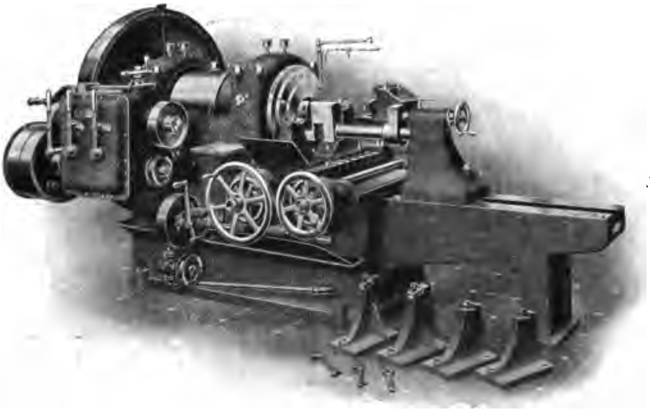


FIG. 79A.—Gardner's crank pin turning machine.

There are several special features in this arrangement.

Multiple throw cranks can be placed within the barrel of the spindle as conveniently as cranks having a single throw, and in addition to the crank pin being turned and finished in alignment with the crank shaft, the pins are round within a maximum of error of ·0005 in. The crank is drawn in Fig. 80. The table on page 70 shows the capacity of the machine, and the time occupied for various sized shafts.

NOTES ON CRANK SHAFTS

Crank shafts of the marine type are built up in sections and shrunk into the arms or webs, and finally keyed. The shafts are made hollow, and at the ends are also provided with stout flanges for attaching them to other cranks or shafts. Built up in this way, the setting out and the machining of the various parts are much more conveniently accomplished than is the case when large solid shafts are used. To make the crank

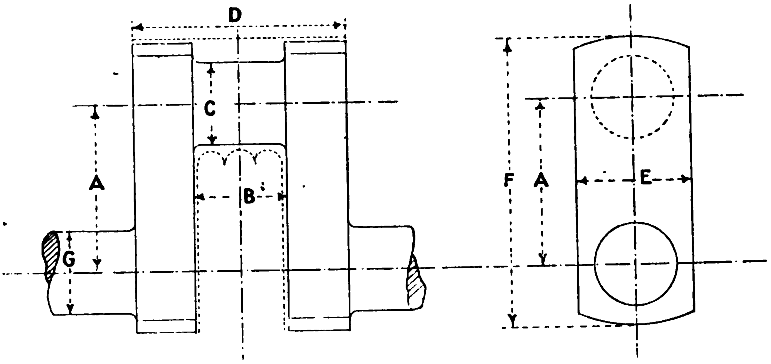


FIG. 80.—Example of 15-in. crank pin machine work.

A	B	C	D	E	F	G	Crowning time in minutes each.	Necking time in minutes each.	Total time.
5½"	3"	2⅞"	7"	3¾"	9¼"	2⅝"	8	25	33
3½"	3"	2½"	7"	3½"	7"	2½"	7	22	29
3½"	2¾"	2"	5¼"	2¾"	6¼"	2"	5	16	21

arms secure, in addition to the two stout keys there are eight massive bolts passing through each arm in their attachment to the flanges. Considering the large dimensions of the crank pin and journals, viz. 15½ in. and 15 in. respectively, the above type of shaft is very light, compared with a solid shaft. However, the hollow shaft is the best to resist twisting and bending for a given weight. The components are secured to the bed of a huge boring mill, and the hole bored in this can be up to 9 in. diameter. A boring head carrying the cutting tools gives great rigidity to the cutting edges, and thereby enables coarse feeds to be taken.

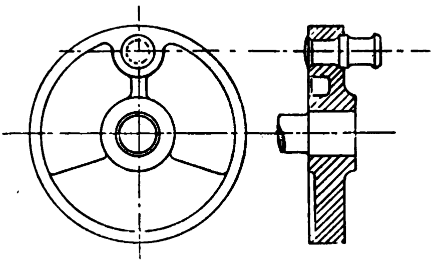


FIG. 81.—Overhung disc crank.

The disc crank (Fig. 81) is a cast-iron plate, cast with cavities on one side to balance the crank pin and connecting rod. The disc is first bored and turned, and the position for the crank pin marked so as to come central with the balance weight cast on the internal face of the disc. The hole for the pin is bored and slightly counter-bored for the collar to take a bearing against when tightly driven up against its key.

In addition to keying, the pin may be further secured by riveting it over at the back of the disc. It will be obvious that the hole for the crank pin must be in perfect alignment with the bore of the disc, as a small error would throw the brasses and rod out of line.

BORING TOOLS, BORING BARS, AND PROCESSES

Boring may be done at the lathe, drilling machine, boring and turning mill, or in a special boring machine.

Small work is generally drilled first, and then a boring tool may enlarge the hole and open it ready for a reamer to finish. Larger work and deep holes are bored with either solid boring tools or boring bars and cutters. Great skill is requisite to bore correctly. Usually the skill is inversely proportional to the efficiency of the tools and the apparatus used. Generally, the lower the standard of the latter the higher the skill of the operator. It is seldom that a machinist is more taxed than in boring a deep hole straight and true to standard size, or to the dimensions of an existing shaft. It will be obvious that the operator has less control of the cutting tools in actual cutting than is the case in turning or machining external surfaces. For instance, a shaft may be gauged very minutely while the tools are in operation, but a hole cannot be gauged until the work or tools are at rest. Again, the gauging of a deep hole is almost beyond all but experts, and the very fact of stopping the machine is a source of danger to parallel boring owing to the springing of the tools or the springing of the work, or both. For this reason when large cylinders are bored the final cut is traversed through without any stop.

To obtain the best results the tools must be stiff, short, and carry a good cutting edge, ground at a suitable angle for the work in hand (Fig. 82).

Boring tools are made from square, flat, or round steel, and have two cutting edges, *i.e.* a leading edge and a finishing edge. There may be one, two, or more tools operating at the same time. When several tools are operating, the material to be removed is divided (not equally) between them. This will be considered more fully under cylinder boring.

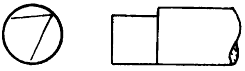


FIG. 82.

BORING BARS AND CUTTERS

The simplest plan of inserting a boring cutter is to drill a hole in the bar at right angles to its length, near one end, and to secure a round steel rod by means of a set-screw, as shown in Fig. 83. The rod is cut just long enough to permit of the ends being turned. To do this, the bar is mounted between the lathe centres, and the rod trimmed at the ends. After this the rod is filed to form the cutting edges, which must be suitably backed off for clearance, and hardened. Each end takes its share in cutting. Another form, and one which lasts much longer without the need of renewal, is fitted similar to Fig. 84, but is made with a more decided leading edge and a finishing edge. In this form the true principle of cutting is maintained, *i.e.* all the cutting is done with the front edge and the curved end, leaving the extreme edge to simply scrape up the walls of the holes finishing them smooth. This type of double-ended cutter cannot be adjusted, but there is a slightly different form when two ways of adjustment are possible. First, a short cutter is inserted and, a setting-up screw at the opposite side of the bar holds it. This setting-up screw should be a tight fitting one having a fine thread. The second plan is to have two short cutters (Fig. 84) with their inner ends bevelled off, these being secured in position by set-screws at right angles as in the first case. The adjustment is effected by forcing the cone-pointed screw S hard against the bevelled surface of the inner end of each tool. In this very useful arrangement the tools may be so adjusted as to keep up to standard size; whereas in the previous cases the cutters must be reforged and turned, then dressed and

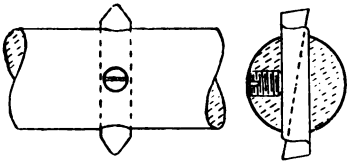


FIG. 83.

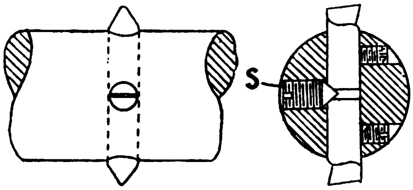


FIG. 84.

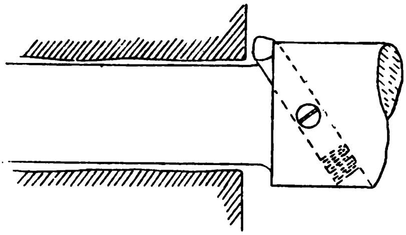


FIG. 85.

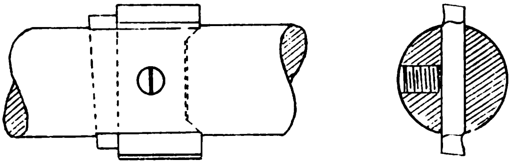


FIG. 86.

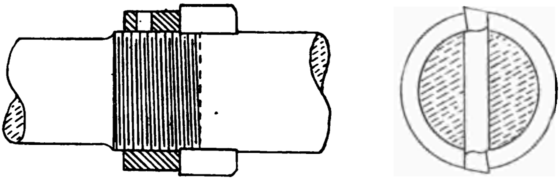


FIG. 87.—Methods of fixing boring cutters.

again hardened. If one cutter only is used there would be delay, therefore a good supply of cutters should be to hand where much boring has to he done. In general engine work, also in the making of heavy machine tools, cutters are forged from flat steel bars and carried in rectangular slots cut at intervals in the boring bars. In addition to the set-screw, the tools are held hard in place by a wedge, or by means of a wedge and cotter (Fig. 86). Instead of a cotter, the bar may be threaded, as shown in Figs. 85 and 87.

In cutting out the slot it is undoubtedly the wisest plan to make it rectangular, instead of tapering one end, and using a taper wedge to hold the cutter in place, or even by means of a cotter and gib. The slot being machined out, the ends may be squared at right angles to the bar.

The cutter should pad evenly against the front wall of the slot and should attack the work with an equal pressure and equal depth of cut on each lip. Now, to obtain this, the cutter must be set precisely level with the mouth of the hole, *i.e.* having faced up the boss a faint scratch made by traversing the cutter on the left side of the boss, should be similar to a scratch made by the cutter being traversed across the right side of the boss. Moreover, the cutter must be fitted evenly tight in the slot by the key or wedge, at every point of the hole. Therefore, the wedge should be *parallel* for *the portion fitting in the bar*, with a slight taper to further tighten it if necessary. This taper portion is not to enter so much, as to act as a check on the distance the wedge is to be driven into the slot. The wedges should be made of annealed tool steel, so that they will not easily burr with hammering. By first bevelling off the corners at each end, the wedge will last a long time without showing any swell whatever. It is necessary to periodically anneal the wedges and overhaul them, filing down any appearance of ragged edges at the ends. If this little matter is neglected there will be found considerable difficulty in fixing a cutter properly, and of extracting the wedge when necessary.

It may be pointed out that tool steel of a uniform width should be used in making the cutters, so that as few changes of wedges will be made as is practicable. As the cutters wear and lose dimensions, they may be ground down to be used in boring holes of less diameters. The heel of each end of these cutters is bevelled to prevent fracture when it is struck. Solid boring tools are used in the lathe. They are forged down and the tool nose bent to a right angle. The cutting edges are next formed in a similar manner to those used on external surfaces. Where heavy cutting has to be done a very stout bar of mild steel is used. This has a small slot near the end, into which a short peg of tool steel is inserted. These bars are fixed in the lathe tool rest, and operate on work attached to the face plate, or carried in a chuck. There are limitations to the depth of cut and the rate of feed in this arrangement when deep holes necessitating a considerable overhang of the bar have to be tooled out.

When it is practicable the bar should be supported at both ends, either in a hollow spindle in the fast headstock or between the lathe centres, but in the latter case the work is stationary, it being secured to the saddle or directly to the bed of the lathe. In the former case the bar takes a housing in a bushing and is fed with automatic motion as in a turret lathe. The cutter, being fixed in the bar, travels with it, or a stout collar may be secured to the bar and the cutters attached to it, this being done for larger diameters. In the latter case, the lathe is essentially converted into a boring machine where the work is fixed on the saddle and the bar is between the centres. But the bar is fitted with a large sliding collar, or head, which is automatically fed by a scew and nut, actuated by gear wheels. The nut is within the sliding head and rotates with it, thus keeping the head only free to move in a straight line. The sliding head or collar is essentially a very good fit and may be relied upon to traverse from end to end of the bar without any appreciable shake. When once the head becomes a loose fit on the boring bar, the hard scale or hard metal will cause the tools to vibrate while cutting. To obtain a very smooth surface there are pieces of hard wood driven into the head alternately with the cutters, the wood acts as a cushion and minimises any tendency of the bar to spring.

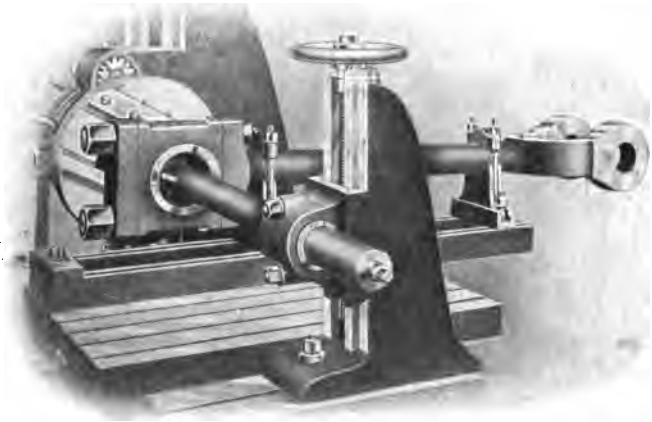


FIG. 88.—Boring a connecting rod end.

In the Marine type the connecting rod end for the crank pin brasses is made with a recess into which the lower brass fits. The top brass is similarly fitted to the cap (Fig 88).

The parts are held together by two steel bolts and grooved lock nuts, the latter being further stayed by screws. The crosshead end of the rod is forked to pass over the brasses and crosshead, but the pin is made fast in the forked end of the rod while the brasses are made a working fit on it. The rod forging is first overhauled for dimensions, then after turning is again set out for machining the flat surfaces, and cutting the recess referred to.

This form is perhaps the simplest and cheapest of connecting rods we have, but after the parts are once assembled, and the bolts passed through and secured by their respective nuts, there can be no correction allowed in the constructional parts unless it is just to ease the brasses to get them to pad uniformly to the crown of the crank ,shaft on which they ride. To do this the journal should be smeared lightly with a very thin coating of red ochre and oil before the brasses are assembled. The fitments are again put together, and after a few turns of the shaft are dissembled. The bearing points will have now turned the colour of the ochre, and these parts must be scraped down until the whole of the surface required is in contact. The process may have to be repeated several times, as it is essential to the sweet running of the engine for this to be a first-class job.

Obviously the greater the care bestowed on setting out, fixing, and the various tooling stages, the less will be the time required for subsequent corrections.

The scraping tool is made from a slightly bent half round smooth file. After bending and re-hardening, the file is ground on the edges and flats until no traces of the teeth are left. The Vee-shaped edges are then carefully oilstoned. Care has to be exercised in using a scraper on brass, phosphor bronze, etc., or corrugations may be made on the surface of the bearings. Once these get in, their removal is most difficult owing to the concave shape and to the antifriction recesses.

"SETTING," SECURING AND BORING ENGINE CONNECTING ROD

To obtain absolute parallelism between the crosshead and the crank-pin bearings is not an easy task, especially in the case of long connecting rods being used. An example, of a simple but accurate and effective character is given in Fig. 88. The connecting rod is fixed in true alignment with the table and the spindle of the boring and facing machine, and secured in the setting blocks; the latter being made adjustable in a straight line by means of projecting tongues which accurately fit in the parallel grooves in the pair of slide bars shown. The advantage of this arrangement is such that after the boring and facing of one hole, the sliding bars may be released and moved until the other hole comes easily within the range of the machine. Thus the axial line is not disturbed while any portion of the work is tooled. The special setting blocks and clamps are so arranged as to leave the ends clear, both for setting and tooling. The examples illustrate work done on a modern surfacing and boring machine by Messrs. H. W. Kearns and Co., Limited, Manchester, to whom I am indebted for the photographs.

Some machines are provided with a table which will swivel into any desired degree (Fig. 88A). These, however, are generally supplementary appliances such as are used on a radial drilling and boring machine.

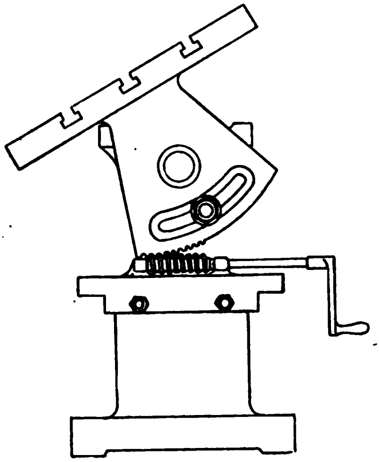


FIG. 88A.—Tilting table for drilling machine.

In taking the above type of connecting rod for tooling at the drilling machine, the holes, being vertical, are not nearly so convenient, especially for facing within the fork, while the under surfaces at both ends will usually require an additional setting. A further advantage is that in the former case the progress of the cutting tools can be seen and gauged easily. Small connecting rods and levers are secured to the face plate of a lathe. This is a sure way of obtaining true alignment (see Fig. 92, p. 81).

SETTING AND BORING AN ENGINE CYLINDER

Fig. 89 shows how an engine cylinder may be mounted in a pair of adjustable setting blocks, quickly set and bored, faced, turned and drilled, etc.

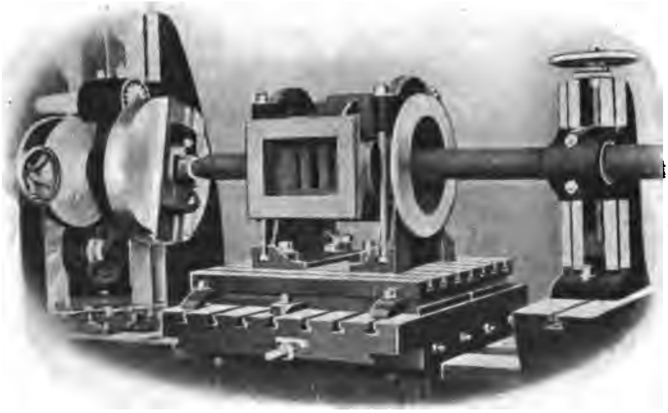


FIG. 89.—Boring steam engine cylinder.

The boring is accomplished by means of a cutter bar fitted at one end within the machine spindle, and carried at the other in a bushing housed in a vertical slide. The machine has some distinctive features for tooling complete at one setting cylinders and such work.

After the cylinder is bored, it is faced, then turned on the flanges and counterbored. The turntable is actuated to bring the steam chest face in position for surfacing, and the valve face and steam ports may be milled at the same setting with a suitable cutter. The convenience of this arrangement is obvious when compared with boring on the lathe face plate, or saddle, or even with the existing arrangement for such work at an ordinary boring machine. The special setting blocks, when once arranged become a jig for all cylinders of the same size, *i.e.* when cast from the same pattern.

In the above case the facing tool is carried on a vertical slide which is directly attached to a stout plate on the end of the driving spindle, thus with a direct drive the action is most rigid, permitting of a higher speed and a courser feed than would be possible under ordinary conditions. In considering the above boring, facing, and swivelling arrangement, the machine is at once a labour saving tool, since one setting only is required for boring, facing two ends, and tooling the steam chest, also for milling the steam ports in the cylinder.

In some cases the cylinders are tooled at three different machines, boring, planing, and milling, respectively, and of course a separate setting for each operation is necessary. Small cylinders are bored on the lathe face plate, the flanges being tooled afterwards, while the cylinder is carried between the lathe centres on a mandrel (see Fig. 50).

PLUMMER BLOCKS—FIXING, BORING, AND FACING

A further example of suitable fixtures is illustrated in Fig. 90, which shows a pair of Plummer blocks secured for boring and facing. Assuming that the castings have been tooled over on their base, they may almost instantly be set in proper position. This is effected by fixing the parallel strips suitably for the first pair, and noting where to place a stop on each strip. The arrangement need not be disturbed until all are bored and faced, in fact the placing of the guiding stops converts the device into a simple jig. The advantages of this machine are further shown in Fig. 90A, boring motor-car cylinders.

Plummer blocks of large dimensions may be bored in pairs, smaller sizes may be held in fours or more. By having the cutters made to fit the bar, changing the bars will then easily be effected without interfering with the cutters. It is however necessary to remove the caps to locate the second bar, and after boring remove it, the facing can then be proceeded with in the ordinary way. Where the work is done on an angle plate at the lathe, one block only may be done the same as though it were carried in a jaw chuck.

It is then usually the practice to mount the blocks on a mandrel for turning and facing; this is obviously much slower work, but the tooled parts may be scraped and polished while thus held.

Before leaving this work, the boring of the blocks can be done satisfactorily in a radial drilling machine, which is to some extent like the lathe, but having the spindle running vertically. Finally, boring and turning mills are very suitable for such work, but the lower boss has to be tooled afterwards, although the support to the bar and the method of driving render this type of machine one of the most powerful to hold and tool up pieces of a repetitionary character. While for wheel, plate, and ring tooling it has distinct points of advantage seen perhaps more in the heavy than the light classes of work.

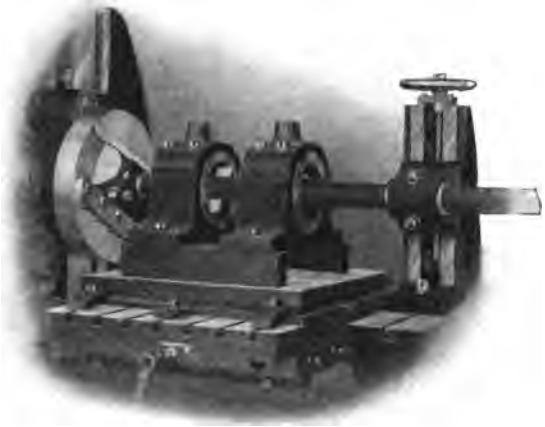


Fig. 90.—Fixing, boring, and facing Plummer blocks.

Clamping Arrangements

A special form of clamp is illustrated in Fig. 91 for holding a piece of work to be drilled. The clamp is bolted to the bed or table of the machine, and the work is securely gripped by a pull on the lever shown. The movable jaw is at all times parallel with the fixed jaw, and the leverage against the movable jaw is obtained by cam surfaces on the operating lever. Referring to the figure, A represents the cam surfaces, B the lever, C shows the movable jaw, D is the yoke, E the spring, F the pipe dies, G represents the wooden dies, and H the adjusting handle. These appliances are intended to hold similar pieces of a given size without the trouble of unscrewing and screwing up the vice or, in the case of a jig clamp, without the removal of the U or horseshoe clips, and re-bolting them for drilling machine, or milling machine work.

In the use of the pipe vice, its principal advantage is in cases where one or more operations are to be performed on a number of pieces of pipe of the same size, in which case a piece of this pipe is inserted between the pipe jaws of the vice, with the operating lever down in close position, the movable jaw is then secured tightly in position against the pipe, and the vice is set. To release the pipe the movement necessary is to simply throw the operating lever upward, the spring E, working against the yoke D, throws the movable jaw C, straight backward, thus allowing ample clearance for the easy removal of the pipe. Then another piece of pipe may be inserted, and with a downward movement of the lever B, the work is secured

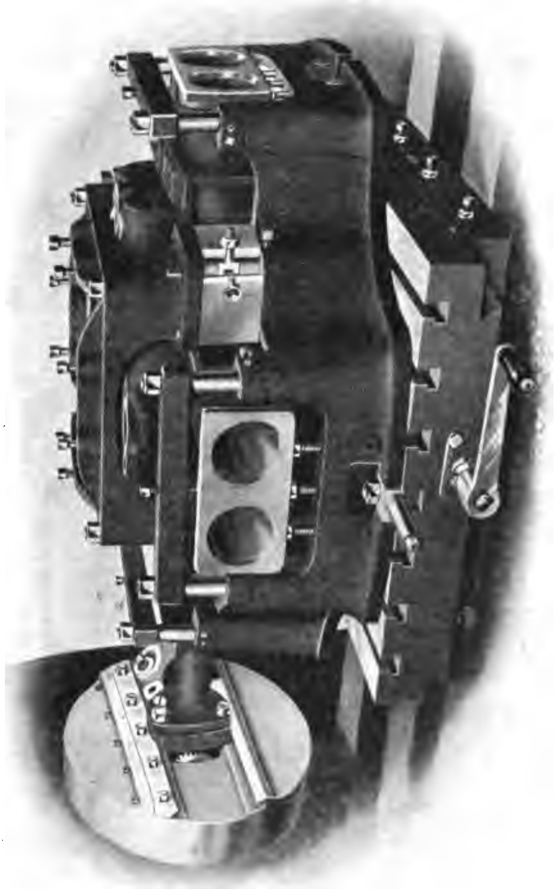


FIG. 90A.—Boring motor-car cylinders.

correctly. In Fig. 91A a quick action jig clamp is shown holding a piece of work beneath a drill. The clamp is bolted to the bed-plate or table, and on pulling the lever the work is firmly held in position for drilling. A movement of the lever in the opposite direction causes the upper jaw to fly up and release the work, leaving ample clearance.

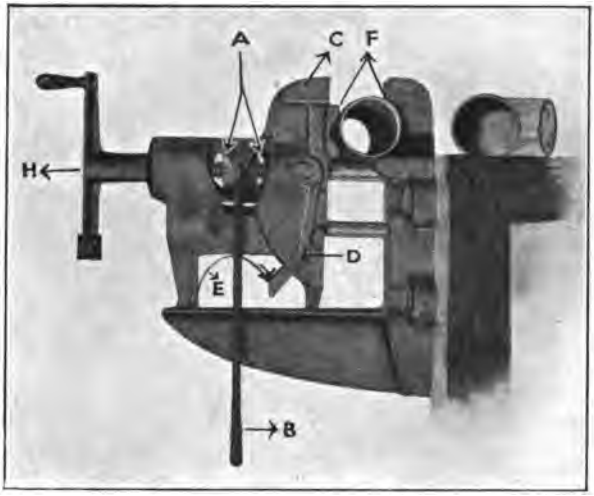


FIG. 91.—Quick action pipe vice.

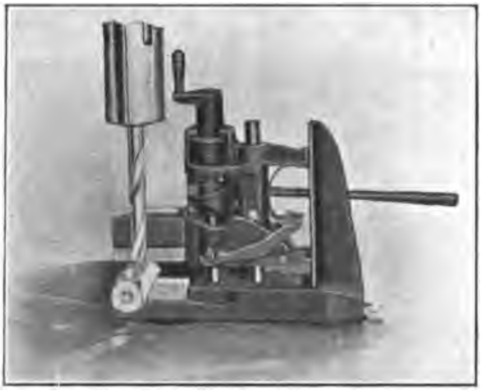


FIG. 91A.—Quick action jig clamp.

In this way a saving of time is effected, especially on work of a similar size or of a repetitive character.

In Fig. 91B, the same arrangement is applied to a grinding machine; its operation is similar to that described, or, by using one bolt, the latter may be made to act as a pivot upon which the work is revolved towards the grinding wheel. The wooden dies, G, are renewable, or may be substituted by others for specific work. These appliances are by the St. Louis Sales Co., U.S.A.

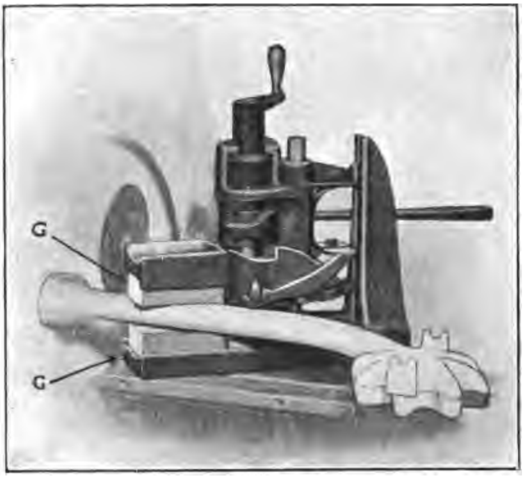


FIG. 91B.—Jig clamp used on grinder.

SETTING OUT EQUIDISTANT HOLES IN A CIRCULAR PLATE FOR BORING

In the above example (Fig. 92), a number of holes are required to be set out for boring at an equal distance apart, and at a given distance from a common centre. There are several ways in which this may be done. The first and probably the most general is to divide the disc into equal spaces in a horizontal milling machine or dividing "engine,"

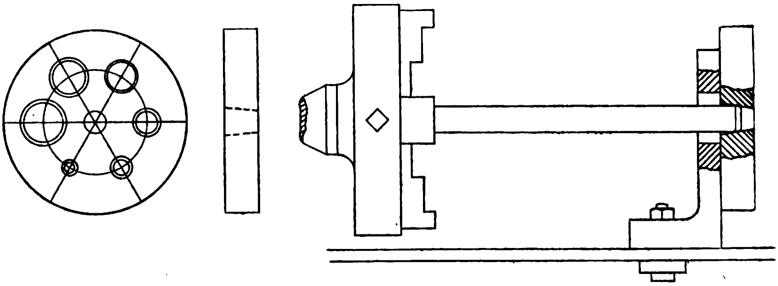


FIG. 92.—Disc set out to be bored for collar stay. Shaft supported in chuck and collar stay.

using the dividing head. Similar accurate divisions may be made in the lathe, when the front gear wheel is provided with a series of rings of holes suitably spaced for any ordinary divisions (see Fig. 48). Failing these the divisions may be very carefully set out on a finely traced circle made with a sharp tool in the lathe, each divison being gauged with a pair of compasses. The centres for boring being thus approximately obtained, a small hole may be drilled in each and tapped to receive cheese-headed screws. There are also a set of small collars or "buttons" bored to pass freely over the screws, but the outer diameter turned or ground precisely to a gauge. In fixing each button is secured with a screw and washer, and minutely gauged both for distance apart and from the periphery of the disc to their outer diameter. When the buttons are satisfactorily located, each one in turn is set to rotate concentrically with the lathe spindle, and removed for the tapped hole to be enlarged to the finished size required. When the discs are in great quantities, then of course one master disc only would be necessary.

The master disc would be used as a jig, and the other ones to be tooled placed in turn beneath it. The exactitude required decides how the master plate should be made and fitted. This branch of engineering is now set apart for expert consideration, and is rapidly developing into a speciality (see jigs, Figs. 62, 63, pages 43–46). Draughtsmen who excel in this work have usually spent a considerable time in doing practical work in the tool room in the shops.

"Setting Out," "Fixing," and "Tooling," a Short Flat Connecting Rod

Two parallel blocks will be used to support the rod at AA (Figs. 93, 94), leaving the bosses free as shown at BB. A pair of trammels with the points set out at 18 in. will mark the centres CC.

The L square will be next brought against each boss, and any error in these will at once be seen and corrected by the twisting wrench, or in the smithy at the anvil or swage block as the case may require. The scribing block can be set to the centre of the rod at D, and a line drawn across the front and back and ends of the bosses. This line must be dotted with the centre punch and the lever turned over at right angles.

With the aid of a pair of compasses the holes for the bore at C and C_1 can be described, and from the centre of these a line can next be marked passing from C to C_1 and C_{11} to C_{111} respectively. The L square may now be used against the face at C, and a vertical line marked on the sides of both bosses. The various lines can now be dotted in and the rod is ready for fixing and machining.

There are two ways of machining up the rod; it may be secured on parallel blocks to the face plate of a lathe, in which case the setting for the first hole will be carefully made, and the centre line on the edge of the rod can be verified along the length by gauging its distance from the face plate, while the evenness of the setting will be gauged by testing the opposite side, *i.e.* the precise distance at which the rod is held from the face plate. To facilitate this setting the rod should be made to rest on the parallel blocks at AA, while on the marking out table, without any appreciable rocking, a few strokes with the file is preferable to additional strips of packing. This ensures that the holes will be bored parallel to each other and at right angles to the faces AA, when the bolts and clips are tightened up (Fig. 94). It will be obvious that if the work is done in this way, there will be two settings of the rod, and the method of fixing severely put to the test.

There is an advantage in tooling the rod in this way: the boss A may be bored, and turned and finished on one side, then, by placing the rod with its bored hole and truly turned face on an axle previously turned and secured to the face plate, set at precisely 18 in. from the lathe centre (see Fig. 95), there remains only to swing the rod central, then support and secure the boss, and the second hole can be bored and the boss turned and faced as in the first case. The remaining portion of each boss will be turned while the rod is carried on a mandrel between the centres of the lathe. It will be seen in Fig. 94, that the supports are immediately beneath the clips and bolts, and that the bosses are kept from springing by a solid support at T while the rod is bored. Notice should be given especially as the work is finally tightened up, for unless there is evenness in the supports the alignment of the two holes will be in error.

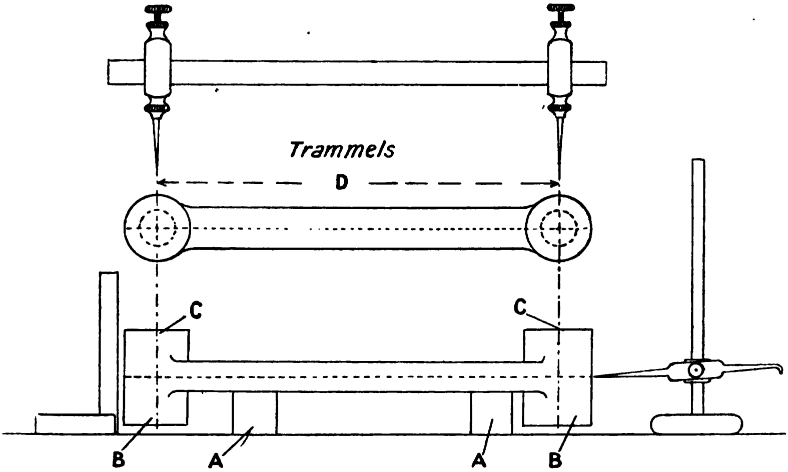


FIG. 93.—Setting out lever for boring.

This work may also be done at a radial drilling machine, and to facilitate the fixing the faces of two bosses may be shaped or milled over immediately after setting out.

If both boss faces are in the same plane they may at once be secured on paralled strips or two collars of equal thickness can be used to support them, this being all the setting that is necessary. When, however, the bosses are not in line, a packing strip or washer of the right thickness must be inserted. In this case each boss will be secured to the table by two bolts and clips, until both holes have been bored and reamed. After one hole has been finished then the arm of the drilling machine will be swung away, and the saddle adjusted until the drill spindle is central with the marking for the second hole. A standard gauge or short-fitting shaft may now be passed into hole, say No. 1, then with a mete touching the machine spindle, or a standard reamer fixed in the spindle socket, the actual distance between the centres may be obtained precisely. After the drill has been passed through, and the reamer inserted ready, the distance gauge may be again used to verify the measurement. When quantities are required a special jig would be made, and the levers drilled and reamed in it at the radial drilling machine.

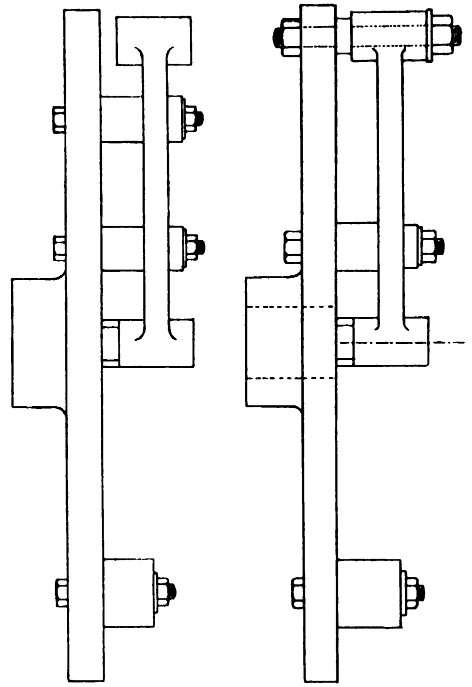


FIG. 94.—Method of securing lever in lathe.

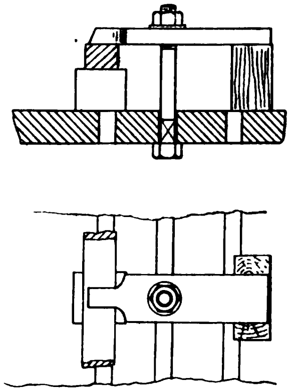


FIG. 95.—Securing lever for machine in lathe. Drilling the second hole.

STATIONARY ENGINE—CROSS HEADS

In marking out, and in machining engine cross heads, care has to be taken to note that the base which must be tooled to fit flatly on the slide bars is also quite parallel and axially straight and true with the hole above it for the piston rod end. Obviously, all lines should be clearly defined and dotted in. The base will be tooled to the dimensions and preferably scraped and fitted to the slide bars. By doing the work in this way the marking can be tested and verified so that when the base is clamped to the angle plate or boring machine table the setting can be accomplished with a minimum of error. A truly machined angle plate can be secured to a lathe face plate and then the cross head placed upon it. Now by the use of a reliable L square, the sides of the work may be set, and the work secured fast to the plate.

To keep the cross head from side movement stops can be fixed to the table of the plate against which the side of the base of the work may butt.

In another form of head the slippers are machined to the proper curve, and the bosses bored and cut, these being afterwards secured to the cross head by means of fine threaded screw, and there retained by lock nuts. In this type the parts have to be adapted when assembled to fit in the slipper ways, the latter having been bored and finished. In the above type (Fig. 96) it will be seen that the holes for the gudgeon pin are bored taper. Now to produce a satisfactory finish to this part of the cross head will require great care, the holes must be tested, preferably by the gudgeon pin itself, or a similar gauge used to obtain a perfectly good fit. The best results are obtained by the use of a taper reamer, failing this, the finishing must be done with a keen-edged boring tool, taking very light cuts. The taper hole for the piston end must be similarly treated with care. The use of an inside micrometer gauge, or special limit gauge, would be at hand in producing duplicates of this work.

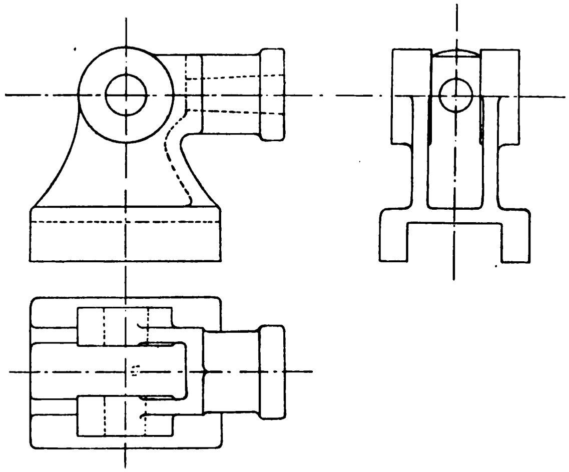


FIG. 96.—Cross head for stationary engine.

NOTES ON PISTONS AND PISTON RINGS

Let it be supposed that a small piston has to be bored and turned for a steam engine. The iron casting is first bored and faced, then mounted on a mandrel and turned a free "sliding in fit" to the bore of the cylinder. After this the width of the piston is gauged over, and grooves are cut out, and their sides truly and smoothly faced up to receive the rings, which will finally be made steam tight in their fit within the cylinder. It is usually the custom to face up the bosses and leave the sides as cast. To begin, the casting is gripped in a lathe, self-centring or other jaw chuck and bored, and the mouth of the hole faced up. The taper is 1 in 13, and can be bored to fit the gauge by swivelling the compound rest to suit. A mandrel M having a screw thread will suffice for combined gauge and mandrel; the piston being held by frictional contact on the cone, and further prevented from getting loose by the grip given by the nut at the end of the mandrel.

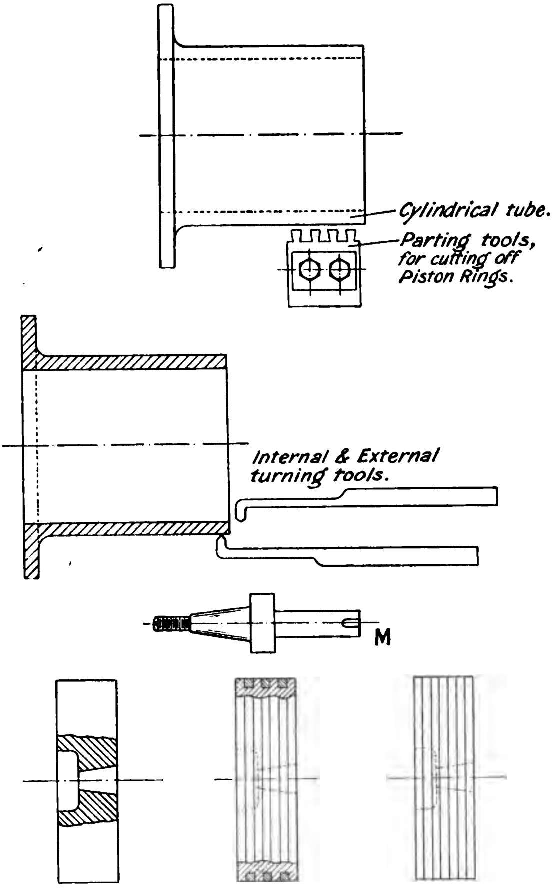

Cylindrical tube.
Parting tools, for cutting off Piston Rings.
Internal & External turning tools.
M

FIG. 97.—Machining piston and piston rings.

The outside diameter will be turned and finished, and the block marked with a horizontal line, and then spaced for the rings, a square-nosed parting tool $\frac{1}{32}$ in. narrower than the groove dimensions will be inserted to the depth required for each groove, and the finishing cuts taken with a sharp knife tool, each groove being subsequently finished by scraping the sides until the gauge will pass, and uniformly touch without pressure. The piston rings may be turned, bored, and cut off (Fig. 97) from a cylindrical tube, or they may when large be cast directly from a pattern. In the former case the tube is turned and bored to the proper dimensions, and then parted off singly or in pairs, or latterly where special machines are constructed to make these there may be six, eight, or even twelve tools operating at once, in this case the rings are turned with a thick and a thin side, quite automatically. In the best practice the piston rings are hand-scraped to a surface plate and fitted into the piston. The piston is shown in three views in Fig. 97. There are, however, many other forms of pistons which are built up so that the rings have not to be forced over.

Notes on Setting out Lathe Headstocks

In ordinary practice lathe headstocks are set out and tooled in sets of 6, 12, or more pairs. For our purpose we will consider a single pair of 7 in. centre lathe heads for a screw-cutting lathe. The cores will be plugged with wood, and a thin strip of tin inserted across the centre of each (Fig. 98), or they may be bridged over with a thin strip of steel. The headstock will be placed upright, resting on parallel strips, and then the surface gauge set to the height of centre, and each hole tested roughly before a line is marked at all. This will show the relative position of the cores to the base, and whether either headstock needs any further packing at any point in their base (Fig. 99). A small amount of error is not serious, but if there is a bent core, say in the loose head poppet hole, it may be considerably helped if a strip of paper or thin cardboard is inserted beneath the end which is found to dip. A line can now be scribed across the centres of each, as shown in Figs. 99, 100, and 102, and the surface gauge finger lowered $7\frac{1}{8}$ in., and a further line marked around the base of each headstock. The heads may now be turned over until the lines marked are in the vertical plane. A bisecting line is next made to pass through the centre of each core at each end, and terminate through the tongue beneath each base as shown. These lines should be finely centre dotted at intervals, say $1\frac{1}{2}$ in. to 2 in. apart, and then with compasses set to the diameter for boring the fast head for bushes, and the loose head for the poppet respectively. Circles can be described and at once dotted in, showing the amount of metal to be removed by boring.

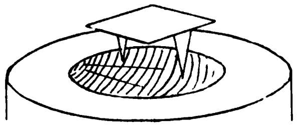


FIG. 98.—Tin strip for centre in wooden plug.

The headstocks can now be set tandem on the planing machine against angle plates for support, or they may be milled singly with straddle mills at the milling machine. Some loose headstocks are awkward to hold. The best plan is to use wooden props at the sides and an angle plate at the front, while the barrel rests in Vee blocks or in a special Vee trench planed out of the centre of the bed. Held in this way a "finger" clip may be used at the outer end of the barrel, and a bracing clip near the front. The props act so as to neutralise or equalise when the cuts are being taken. Reference has been made to the use of angle plates. These, of course, are the planer's "sheet anchor" for such work, and if the shape of the work prevents the plate from actual contact then he inserts parallel packing or other strips to fill up the gap.

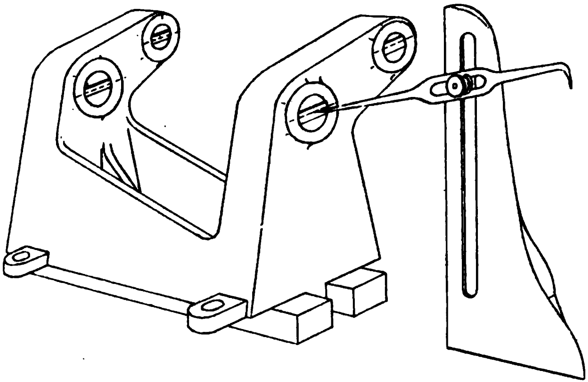


FIG. 99.—Marking out fast headstock of lathe.

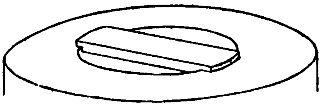


FIG. 99A.—Centre piece of metal for cored hole.

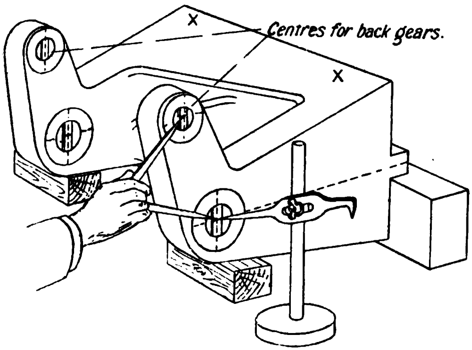


FIG. 100.—Setting out fast headstock of lathe.

In modern practice, where the work is often repeated, specially designed holding "jigs" are employed wherever practicable; in such case a number of similar headstocks would be secured and tooled at one setting, the fast headstocks being planed first because there is considerably more work to be done afterwards to these than to the loose heads. A gauge is fitted over the tongue, and each side being planed down to the line, the fast headstocks are removed and the loose heads secured as above stated. After the planing is all done, the base and sides of each head are truly scraped down until they fit evenly in the "ways" of the lathe bed. This is most important before being secured to the table of the boring machine. Error is easily corrected at this stage, whereas, if left until the boring is completed, a slight error being then removed there is a danger of altering the alignment of the two headstocks.

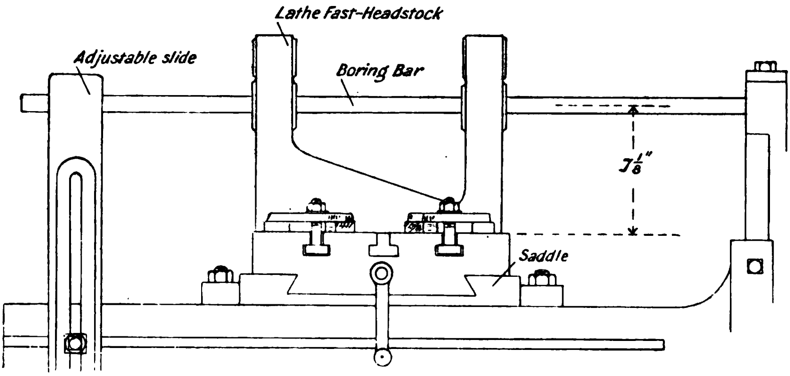


FIG. 101.—Machining fast headstock on boring and facing machine.

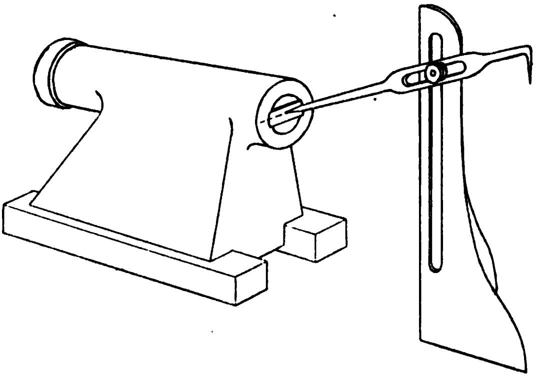


FIG. 102.—Setting out loose headstock for lathe.

Before fixing the work, the machine is carefully set, *i.e.* the spindle and its end bearing are adjusted to carry the boring bar at precisely $7\frac{1}{8}$ in. from the table (Fig. 101). This being done, the slides are secured, and not further disturbed until all the boring is completed.

BORING LATHE HEADSTOCKS

The wisdom of this is obvious, especially when it is seen that any pair of headstocks may be selected from stock and no appreciable error can be detected. There are a few other points of importance in this work, viz. the boring bar should be as *short* and as *stout* as is practicable, and the bearing as *close up* as is convenient. This reduces the "spring" or vibration of the bar to a minimum. In boring the fast headstock, both holes are tooled simultaneously with roughing cuts, following cuts, and generally with finishing cuts too. A shell reamer can now be fitted on the bar and each hole made precisely to standard size. Tight-fitting bushes are next put in the bored holes to give additional support to the bar during the operation of facing and tooling up the bosses externally where this is included. Supported in this manner there is not much risk of the bar being bent. On the other hand, were the holes to be faced and the bosses trimmed without the bushes being inserted, the bar would be liable to bend even when made of crucible steel with a high percentage of carbon. A heavy cut has to be taken to form the recess for the flanges of the phosphor bronze at the outer face of each hole. These, however, are cut as easily as turning on solid external metal owing to the rigid support given to the bar by the fitting bushes referred to.

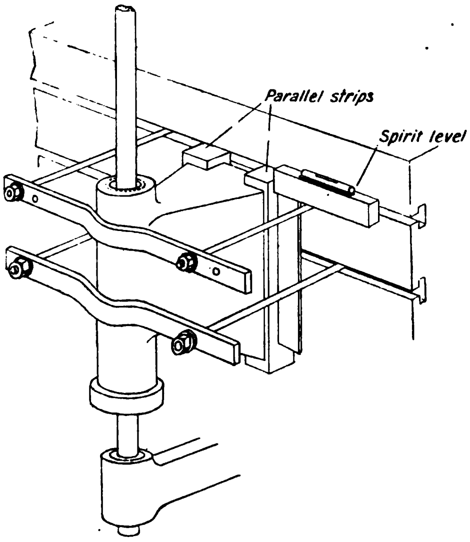


FIG. 103.—Boring loose headstock at radial drilling machine.

A finishing cut is given to each recess, and the heads are taken away for "bushing." Fig 103 shows how the headstocks may be bored at the drilling machine.

This again, is most interesting and particular work. A gauge turned to the correct taper is supplied to the latheman. The gauge should have a fine line turned near to the large end showing the depth to which the gauge is to enter the bush. To obtain the correct taper (if it is not given in degrees), the gauge is placed between the centres and a sliding tool secured in the clamps with its *nose precisely on the centre line.* The rest is then swivelled approximately to the taper and secured.

Boring and Turning P. B. Bushes

Failing the use of a conical gauge, a bush mandrel as shown in Fig. 52 may be used.

A thin strip of metal is just made to pass and perceptibly touch between the gauge and the tool nose. The transverse slide can now be withdrawn a little and the tool traversed by means of the slide rest screw, until it is near the opposite end of the gauge. Then the strip of metal must be held against the gauge, and the tool brought back to its original position. Alteration of the swivelling rest is made until the strip will be gripped at any point along the periphery of the gauge. All this is assuming that the fast headstock is truly fixed for boring and surfacing when the loose headstock is withdrawn.

Where this is not the case the gauge should *not* be held between the lathe centres, while the taper is obtained, but secured and set truly in a jaw chuck, and the taper transferred as above. This being satisfactorily accomplished a phosphor bronze bush can now be tightly gripped and set truly revolving in the lathe chuck and a facing cut taken across the mouth of the hole, followed by a second to smoothen and true it. Beginners should note this, because the gauge has to be passed after the hole is tooled, and if the surfacing had to be done after the boring it is just possible that enough metal to do the work properly had not been allowed for, consequently the gauge would penetrate the hole too far. Near the surface phosphor bronze is sometimes found "pitted" with small holes, and for this reason additional cuts are taken to obtain a clear surface. A final reason why it is the safest plan to face up first is that the legs of the calipers can at once be correctly placed when gauging the progress of the boring.

The best results are obtained when the tools are ground almost flat on the top, and Vee shape on the nose with the point slightly rounded off.

The following points are a summary:—1. Use a stiff tool of air-hardened steel. 2. Place on centre line so as to project as little as practicable. 3. Have the saddle locked to the lathe bed. 4. The slides and fast headstock spindle adjusted to work without shake. 5. Frequent use of inside calipers as the boring nears completion. 6. Have sharp tools for finishing cuts. 7. Use a hand scraper to planish or burnish the hole and true it until the gauge touches the surface entirely. 8. Especially notice that the mouth of the hole is sharp. This can only be obtained in hard metal by using very keen-edged tools, and by taking very fine cuts when finishing. There is always a certain amount of "rounding" in this kind of work, the tool looses its edge, and the distance the nose is from the clamps makes it a difficult matter to keep it from springing away.

To turn the bushes for a single pair of headstocks, the conical bush used for the spindle end can be turned and carefully fitted to act as a mandrel for the work. When the work is done in this manner there is no risk of error. The recess in the bearing will be gauged, and its dimensions transferred to the flange on the bush. In a similar way the bore will be gauged, but the thickness for the flange will be turned to a "depth gauge." The calipers must pass over the diameters of the bush just perceptibly stiffer than would be the case in making a sliding or revolving fit, because the bushes must fit tightly when in place. After carefully overhauling each dimension, the bushes can be satisfactorily fixed by drawing them into place with a stout bolt and nut and large washers made with truly turned faces. As the bush goes further and further into its place there must be more washers added until the faces are quite level, as will be the case when the bush is properly home in the headstock.

Notes on Fitting up a Loose Headstock

We will consider the poppet first, in fitting up the parts for the loose headstock. The bore of the head is $2\frac{1}{4}$ in. and a piece of $2\frac{3}{8}$ in. × $12\frac{3}{4}$ in. mild steel can be sawn from the bar, faced, and centred, and a hole bored at one end 10 in. deep × 1 in. diameter. A self-setting arrangement is given in Fig. 104, which consists of a pair of Vee blocks cast on the face of an angle plate, which are planed at right angles to the base and to an angle of 45° to the vertical. There are two clips required to hold the work in the Vees, and tapped holes are provided for the securing bolts.

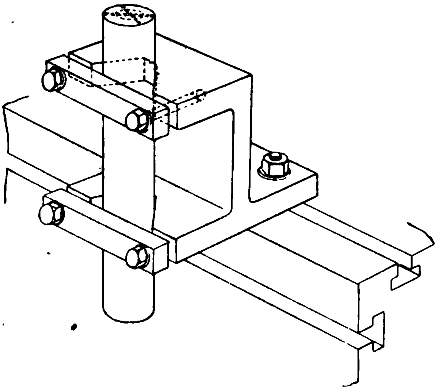


FIG. 104.—Device for securing lathe poppet, or short shaft for drilling.

The base is made extra thick so as to take the strain when the shaft is made to overhang the vertical face of the radial drilling machine table. Supported in this manner the arrangement at once becomes a jig, since all straight pieces of an equal diameter are set perfectly vertical and axially central without alteration at the base in any way. By having a Vee notch cut in two or three pairs to a different depth, a range of diameters can be accommodated and the sizes stamped on the clips. When the work must be secured in the lathe for boring an arrangement is given in Fig. 102.

After the hole has been drilled the short plug is inserted and welded in. Care has to be exercised in getting the end of the barrel to a proper welding heat and at that instant it must be withdrawn to the swage block and with light but rapid blows, closed. Diametrically, the shaft will be less, but some of this can be restored by "up-setting" the end on the anvil after the weld is completed (unless there has been some heavy and uneven hammering); the poppet can be taken to the lathe. In case the poppet is bent, it may be "set" fairly true to a straight-edge by a few blows on the swage block and finally trued with the cramp and links.

In the lathe, the ends will be faced, and two cuts taken over the whole length of the work, after this, one end is gripped in a self-centring chuck and the other supported in a stay fixed near to the opposite end (Fig. 105).

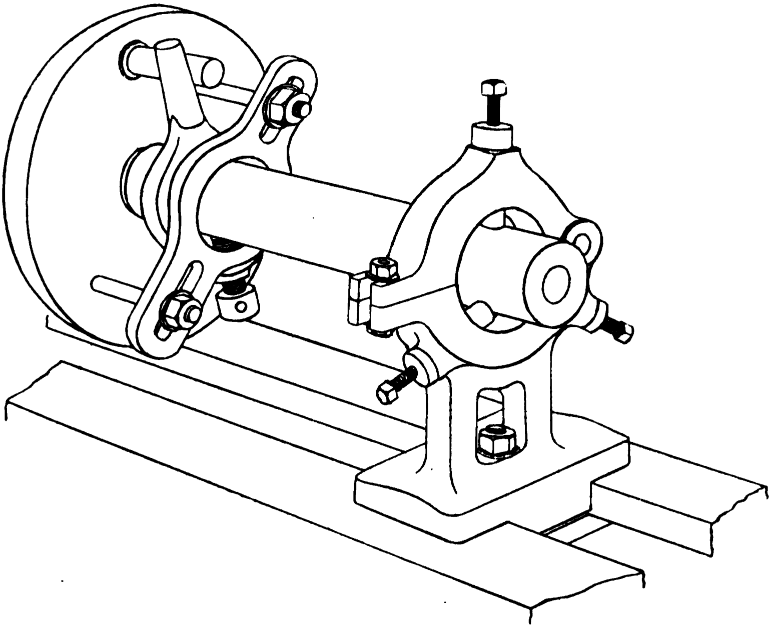


FIG. 105.—Method of securing and supporting loose head poppet for boring and screw cutting.

FITTING UP A LOOSE HEADSTOCK

The first end to be bored is the one to receive the centre. A drill will be passed through to the "chamber," making a hole the size, or nearly the size, of the shank at the small end. If the taper is "known," the rest can be at once set, and the hole opened out until the mouth is large enough for the reamer. The finishing is most important, the fit must be tested to a taper gauge, and the hole scraped with a half-round scraper until there is perfect coincidence from end to end of the hole.

A thin film of ochre and oil will show the points of contact as the work proceeds to completion. A taper plug of steel, with an extending portion for a carrier, can now be inserted, and the work removed from the lathe, until the jaw chuck is substituted for the ordinary face plate. This being done, the work is reversed, the plug riding on the lathe centre, while the carrier is secured to the poppet by a cross strap and two plates, or washers and bolts and nuts, precisely as in Fig. 105.

The square thread screw, $\frac{3}{4}$ in. Whitworth, will be measured at the base, and the hole bored to its dimensions ready for screw cutting with a left-hand threading tool. The boring tool should be used to clear out the back after boring, so that the screw-cutting tool may make a good start. A stop for the saddle to come against before each cut is taken is fixed to the lathe bed, this prevents the tool being slid in too far, and also acts as a guide for the nut-box lever for screw cutting, as the leading screw reaches the proper starting place relative to the mark on the spindle. When odd threads are cut, the stop will be also fixed for even threads, but the nut may be engaged at any revolution of the leading screw. The screwing tool is inserted and the thread cut, leaving a small amount to be removed with the square thread taps. The tap is inserted and the tap wrench fixed, then the poppet centre is used to hold up the tap perfectly straight, while the belt is moved by hand. Finished in this manner, the thread will be straight and truly cut, whereas if the tapping is left to the vice hand for finishing, the taps may be inserted more or less irregularly. A small centre screw is fitted after tapping, so that the poppet can be turned in the lathe as though it were a solid shaft (see Fig. 106). It is a very good test of the accuracy in setting and tooling if, when the lathe is revolved at a high speed, the poppet shows no error as it rotates. Great care should be taken to have the screw centre evenly fitted on the collar face, otherwise the outside diameter of the poppet will not be turned concentric with the screw. This is not likely to occur if the screw cutting has been done in the above manner, but in such cases where there has been too much trusted to the taps in the vice. Before the final cuts are taken, the centres should be overhauled and reground, if necessary, to ensure the whole of the work being axially straight from end to end. The headstock can be beautifully burnished (Fig. 107), and any irregularities removed after boring by placing it on a lead lap and by lapping it out with "flour"-emery and oil. The emery must be put on the lap near the centre, and as the lap is rotated in the

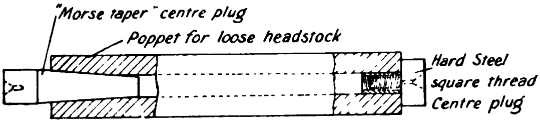


FIG. 106.—Lathe poppet in section.

FIG. 107.—Lead lap.

lathe at a high speed the headstock is slid along "to and fro," this will spread the emery in a thin layer over the surface of the lap. Then, as a little oil is added and the work constantly kept on the move, the grinding or "lapping" out should soon be complete (see Fig. 108). There is much skill and judgment required to properly do this work, but unless it is properly done lapping had better be substituted by "grinding in" the poppet, which is, however, almost as difficult. The emery will, in the latter case, have to be used very sparingly, as there is a great tendency to scour out (grind) the mouth of the hole to a larger size than the poppet requires if too much is used. For this reason the poppet should be ground in from the back, then, when it reaches the front end it will be a good fit. As the work advances the poppit should be withdrawn, and it and the hole perfectly cleaned. Oil alone is put on the poppet, and a thin layer of emery and oil put down the hole at this part, which has not yet been ground. This practice has been treated in detail, but it is so easy to treat the work wrongly that we think a full explanation necessary.

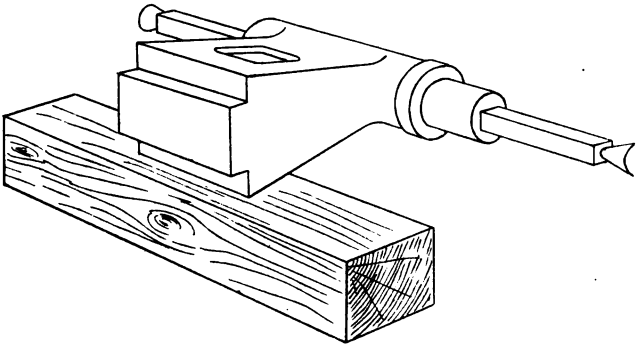


FIG. 108.—Lapping out loose headstock in lathe.

After the end is once protruding sufficiently to get a carrier on it, the poppet is ground until it may be drawn through by one hand steadily with just a stiff fit. Again the parts are thoroughly cleansed, oiled, and chafed, until a good sliding fit is obtained. Referring to the sizing cut on the poppet, this can be taken across the whole length at once if there is a small carrier placed on the end of the centre plug. A few strokes with a smooth file will be necessary if the traverse marks are visible, then a pair of polishing clams are used to finish the surface bright, before grinding is attempted. If this is left until after grinding there are sure to be some marks left permanently visible, and therefore objectionable for finished work. The screw will be turned and fitted to its back plate (bearing), and the hand wheel secured with its nut and washer. To test the correct working of these, place the stem in the vice, put on the plate, and secure the hand wheel with its nut and washer, and then, if correctly fitted, the plate can be rotated freely but without any perceptible shake or end play. This all being satisfactory, the parts are disconnected, and the square thread screw can be cut. Similarly with the nut the stop will be used, or the tool will be instantly broken by winding the saddle too far, and allowing it to collide with the collar C. In some cases a small hole is drilled, into which the tool can enter at starting, but as there is no necessity to have the thread actually "full" up to the face of the collar, the cut may be put on gradually immediately after starting, thereby leaving a much stronger screw than is obtained by the former method.

Boring Lathe Headstock

Originally, *i.e.* before the system of duplication of parts, many of the best machine tool makers fitted both headstocks on to their own lathe bed, thus boring them in their final place. This was done as a guarantee that the height of the headstocks would be equal, also that the respective holes bored would be in precise alignment with the surface of the lathe bed. The lathe would be located either beneath the main shaft or a special counter-shaft used for the purpose. There were advantages in the system, but it was too slow for modern practice, as quantities of the same kind of lathe were demanded. Therefore, special boring machines were used, these being capable of holding various kinds of headstocks. Another point of importance is that, by the latter system, the lathe bed being entirely free, other work of construction could be proceeded with at the bed while the headstocks

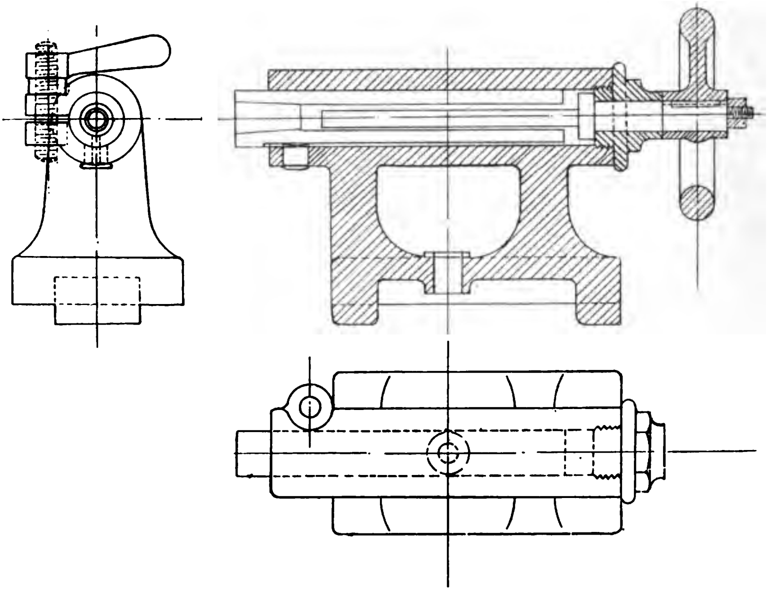


FIG. 108A.—Views of loose headstock for lathe.

were being bored out elsewhere. Very large headstocks can be conveniently bored in place, but these are tooled with a portable boring bar having a sliding head, which appliance can be used wherever it is desired to place it.

Small headstocks may very conveniently be secured to an angle plate and bored in the lathe. The way this is done for great quantities is to keep one headstock for a pattern or gauge. This is fixed on the plate and set perfectly true, then one or two stops are located to keep it straight sideways. After removing this, all fast and loose headstocks are tooled without interfering in any manner with the setting. When a large batch has been bored, the outer diameters are finished by turning, scraping, and polishing, each headstock being carried on a mandrel.

It will thus be clear that, as the angle plate base is truly horizontal, the holes can be made accurately straight, and by a series of light cuts and a reamer each bearing will receive the phosphor bronze bush. This is an example of interchangeable system of working. Fig. 108A shows a loose headstock of a slightly different construction.

NOTES ON LATHE SADDLE

The saddle is also an important factor in lathe construction. So very much depends upon its design, and ultimate precision. The cutting tools can only hold rigidly up to the work when the saddle and slides are properly fitted together. Essentially the saddle rides upon the bed, gripping it, but not so tight as to prevent free movement yet not in any sense perceptibly slack. The surfaces must be truly flat, and the Vees a distinct counterpart of the lathe bed.

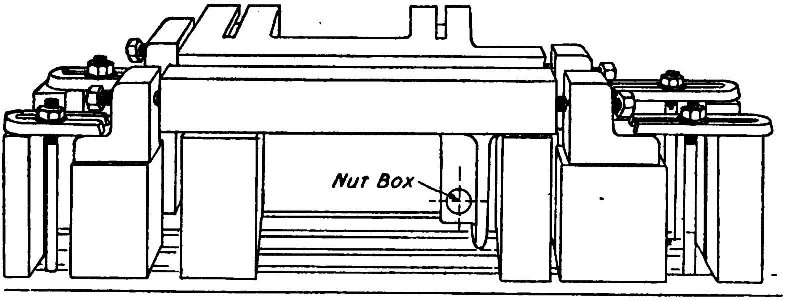


FIG. 109.—Lathe saddle secured to machine table for milling or planing.

The casting is faced on the top first and inverted on the bed of the planing machine and surfaced, then the Vees are tooled out to fit the gauge, after this the casting is again inverted and the transverse slide ways tooled, and a finishing cut taken across the whole of the upper surface; the ends and sides being tooled over, the casting is removed.

It is a growing practice to have as few parts detachable as possible, so as to give increased rigidity, it would almost appear that this is to save time in handling the various parts, and fixing them in place. But this is not actually done to economise; as a fact, many pieces which were of a simple character have become complex when cast as part of pieces to which they were formerly attached by screws or other fixtures.

An example of this is seen in Fig. 109, showing the nut box for the guide screw. This had to be specially considered when the saddle was planed, and again when tooled at the milling machine. The time occupied in overhauling, setting out, fixing, and tooling, at the various machines, was considerably increased because of the nut-box being cast as a part of the saddle; this being made, as is now customary, having facing strips on which the nut will slide when finished and at work. To obtain the right position for the bore to receive the guide screw, namely, immediately over the centre of the nut box referred to, was sufficient in itself to require special care, but these parts had to be considered not alone, but in conjunction with the saddle base for surfacing, and for alignment longitudinally also with the surface of the tranverse slide ways, all of which had their limitations, beyond which no alteration could be considered. After planing or milling the next step is to slot out the sides of the nut box, the setting for this being an easy matter, having the tooled face to rest on and the sides for setting the work parallel with the tool slide. Slotting is not so sweet a cutting action as turning or planing; the tool necessarily must stand out from its support a considerable distance, and by the time it has arrived at the end of its stroke, the ram carrying the tool will also have descended considerably below its support in the slides. This obviously tends to hold the tool off from its cut, and can be well seen after the tool nose has been re-ground and brought in contact directly with the surface it was operating on before grinding. For this reason slotting is never resorted to for any precise work if any of the other machine tools can be utilised for the same purpose.

There are, however, many instances where the slotting machine can cope with heavy work with despatch; an example of this occurs in cutting out the frames for locomotive engines, several plates are secured together, and are operated on with two tools. A further case may be cited, viz. the cutting out of huge slabs of metal to form the crank portion of heavy crank shafts. There are two holes drilled at the proper distance apart, and the slotting tool commences its cut or terminates it into the holes as is found convenient. The tool is made to act in line with the bed, or it may be turned so as to cut at right angles as is requried.

SLOTTING MACHINE—DIAGRAM OF MOVEMENT

In addition to the longitudinal and the transverse feeds the table will rotate. These feeds are all self-acting and thus connecting-rod ends and other work having straight and circular parts can be treated.

Machines of a small size are capable of doing a variety of little work, but usually the parts have to be subsequently fitted, or at the least dressed up. A duplex tool-holder can be fitted with two tools made to operate at the same instant on the two adjacent sides of a series of nuts.

On the main driving shaft a cam arrangement is provided in the face of a disc; the cam carries a roller, and on the end of a lever is an axle, which permits the roller to rotate; as the cam approaches the lever is lifted and it quickly drops again to its normal position, but, in lifting, since the lever at its opposite end carries a connecting-rod end, this operates a pawl which engages with a pinion on a motion shaft. An intermittent movement is thereby obtained to the feed screw of the transverse slide or to the longitudinal slide as desired. From the same source automatic movement may be transmitted to the table when circular parts have to be tooled.

The drawing, in Fig. 110, illustrates the important parts of the slotting machine feed motion above referred to.

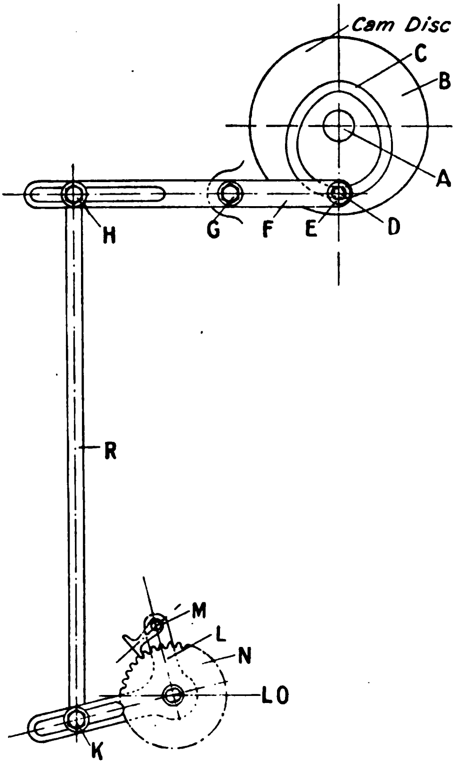


FIG. 110.—Slotting machine. Intermittent feed motion.

On the main driving shaft A is keyed the disc B, on the face of which is seen the cam race C, and the axis of the roller D. The latter is pivoted at E, on the lever F, which is free to move at a point G. Near the opposite end of the lever F, and secured at point H, is the connecting rod R which communicates motion to the bell crank lever L from a point K. The catch or pawl M engages with the teeth N, as shown, or by reversing its position the wheel is fed in the opposite direction.

To obtain the feed action at the precise instant the cam must be made to strike just as the ram carrying the cutting tool is at the top of its stroke. Of course the ratchet may move one, two, or more teeth of the wheel N, and thereby vary the feed. This is effected by shortening or lengthening the distance KL.

SHAPING MACHINE QUICK RETURN

In Fig. 110A, a general arrangement is given showing the link motion for obtaining a quick return to the ram carrying the cutting tool. The path of the link L is indicated by the dotted line.

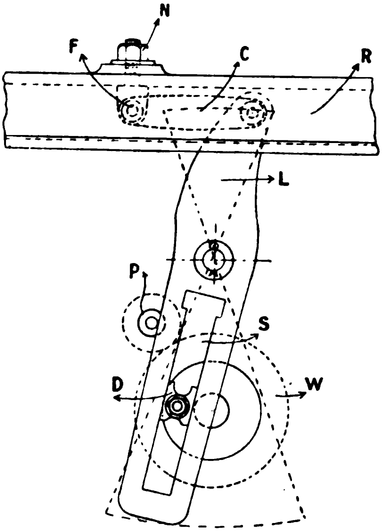


FIG. 110A.—Link motion for shaping and slotting machine.

Motion is communicated from the driving shaft and pinion P to the spur wheel W, and thence to the die D, which is free to slide in the slot S. As the die rises in the slot it approaches the pivot or axis upon which the link rides, but on its descent the distance is increased.

In this way the link is made to vibrate in a variable manner; now the opposite end of the link is attached to a connecting rod, C, this being also secured by an eye-bolt or knuckle at F, which is attached to the ram R, and retained by the nut N.

Therefore, as the spur wheel W revolves uniformly, the link first pushes the ram and the cutting tool, and then pulls them back, the forward movement being steady while the cut is being taken, but much quicker on the return when the tool is free.

In the above case there is a central drive to the ram, as shown by the connecting rod, which is dotted, it being within the walls of the ram.

This form is now much in favour, and is taking the place of the side drive for the machines of medium and heavy type. The feed motion is also now attached to the saddle for the above machines, but those of a lighter build are sometimes fitted with a saddle feed, as shown in Fig. 110.

NOTES ON CORED WORK

A "core" in a casting is an opening in the metal. The hole may be of any desired shape or position. Cores may pass through the work as in a pipe or cylinder, or only partially through; the hole is then blind. Many castings in iron, steel, or brass, which have to be bored out to fit on shafts, spindles, etc., are cored out for three reasons. The first is to reduce the weight of the casting, the second to economise the time in tooling operations, and the third to form a way for the inlet of steam, gas, air, or water, and the outlet of the same. It will be clear that the weight of the casting is a matter requiring close attention, and when well considered the metal is distributed with a view to give strength where it is required, and lightness where rigidity is a less important factor than elegance or economy.

The management should be alive to the conditions necessary in the machine shop, to cope with cored work under the varying conditions in which it occurs, in the various castings which are to be tooled to gauges precisely accurate.

Good judgment is therefore required in deciding when castings are to be produced solid and when cast with a core which is to be bored to a standard dimension.

Generally short work may be safely cast with a core, such, for instance, as pulleys, wheels, bushes, collars, and similar parts. It is, however, often extended to small but long or deep holes, in which cases there is usually a very troublesome task set to the workman, namely, that of straightening a hole with the cutting tool. It is a slow and often difficult operation to properly restore to truth a hole that has been cast in a piece of work, when the hole leans or is taking an eccentric path, getting worse as it deepens.

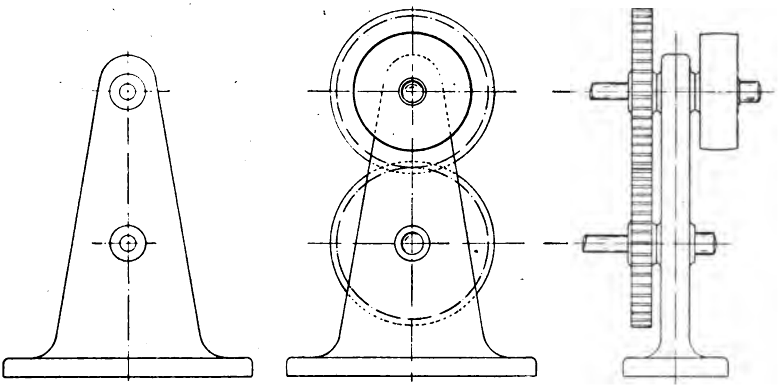


FIG. 111.—Cored bracket and gears.

Let us consider a simple case, that of opening two cored holes in a cast-iron bracket, where each hole will form a bearing for two shafts which will run side by side, and to which gear wheels will be keyed (see Fig. 111).

We will assume that the gears are (A) cast from an iron pattern; (B) cast from a moulding machine mould; (C) machine cut from cast-iron blanks.

Now that the system (C) is in general operation, in most manufacturing engineers' workshops, the centres would be identical with the drawing, and the work will be quickly secured and bored through a jig, without any setting whatsoever, the drills being guided to their work. In jobbing workshops, and such as have not yet adopted the system (C) for all work, either (B) or (A) will be in use. The gears should be bored, turned, and their respective centres obtained and transferred to the bracket. It will now be clear that since the actual centres for the boring can only be decided after trial of the pair of wheels, no previous fixture can have been made in readiness for the work. Therefore, the cores, after plugging, will be lined out for the actual position and circles described, and centres popped; but the holes are cored eccentrically with the marking out, and as a drill will always take the course of least possible resistance, it becomes a question which machine tool is the most suitable one for producing precise work. The lathe comes first, because the operative is a skilled mechanic, and capable of correcting work "out of truth," and by his long experience, good judgment, very careful setting and gauging, he will succeed in producing a bracket with the two holes correctly located. The task, however, is a slow and expensive one, because of the light cuts necessary, and the abuse of the tools caused by the sandy scale in the hole. Actually this work could be done quite satisfactorily at the radial drilling machine if a boring bar taking a bearing in the table beneath the work were used.

The arrangement of a pair of gears on their respective axles is given in Fig. 111, and needs no further remarks. Were twist-drills used in correcting or even in enlarging holes of the above kind, the cutting edges would be quickly dulled, and, if small in diameter, the drills would most likely fracture, if of the high-speed type, or bend out of line if of carbon steel.

NOTES ON THE SETTING OUT AND MACHINING OF AN INDEPENDENT FOUR-JAW CHUCK PLATE

In Fig. 112 a chuck body casting is to be turned and fitted up with four independent steel jaws, each jaw being actuated by a steel screw, the nut for which is cut within each jaw respectively. In the first place the chuck body is mounted on the table of a boring mill, and bored, topped, and faced on both sides. Held in this manner the work would be machined quickly and at a less cost than by turning and boring in the lathe. It may, however, be accomplished by gripping the casting by its boss and turning and boring the piece in a universal or self-centring jaw-chuck. In some modern lathes the turning and boring tools are held in separate rests and can therefore be fed to the work quite independently, but may be operating simultaneously. Where quantities of the same type and size of jaw-chuck are required the tools, bars, and cutters may be carried in special or turret heads, and thereby reduce the actual time of tooling to a minimum, the operations being simply repeated until the whole set is completed.

In reversing, for tooling the boss and the remaining portion of the face, the castings will be gripped by their rim, and the surface set truly by the side last turned. To considerably facilitate this setting, also to control the truth of the work, a boring bar may be secured to the turret-head. This should be a sliding fit through the bore of the work, and finally be strengthened by the support it obtains fitting the hollow spindle in the fast headstock of the lathe. By means of this arrangement chuck plates, face plates, fly-wheels, and all similar work can be rapidly set, re-set, and tooled at speeds and feeds much in advance of any which might have been obtained previously.

The next step is the marking out and machining of the turned plates. The shape of the castings are of two kinds, as shown in Figs. 112, 113. In the former case the body of the chuck plate is cored with four rectangular apertures or slots for the reception of the four steel jaws. The front of the chuck plate is whitened near the edge of each slot, and a centre line AB is described, above and below AB and at equal distances from it, the precise width of the opening is indicated by *cd* and *ef*. The casting is then given a quarter turn and a centre line, for the other pair of slots is drawn at GH, with *lm* and *no* above and beneath it respectively, as in the former case of AB, *cd* and *ef*, Figs. 112, 113. A circle may now be described bounding the root of the slot at each end, and by setting the surface-gauge to the circles, lines RS and TU respectively may be drawn. This completes the lining out and, having dotted in the setting, the plate is ready for machining. An end mill, vertically driven, will open out the slots to the correct width, and by means of the automatic feeds for transverse and longitudinal traverse, the four slots can be tooled at one setting.

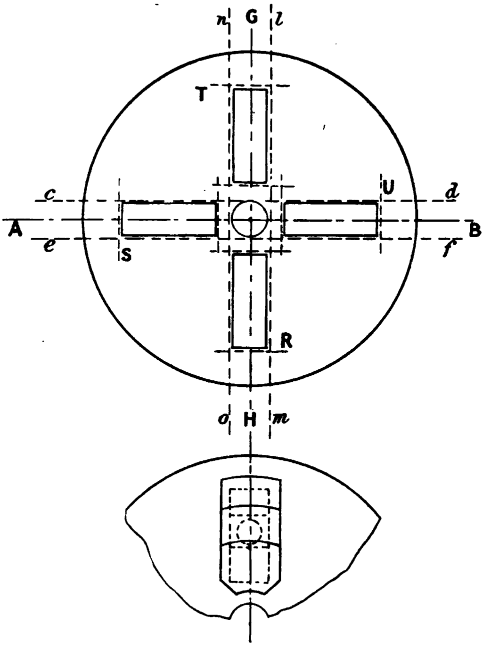


FIG. 112.—Setting out jaw-chuck body casting.

A bolt through the bore will suffice to hold the work down after setting until the other bolts and clips are secured; packing strips could be conveniently introduced to support the rim, these always being placed against a bolt and clip. When the milling is done the corners must be removed at a slotting machine. To get the work re-fixed for this operation it might be thought, why "mill" and then "slot" the work, when slotting could dispense with milling? Moreover, there would be only one setting instead of two required. The principle of milling is unique, by it the work produced is up to standard, and will rarely need subsequent correction or dressing. The milling tools are so keen in their cutting, and the feed is extremely fine, that a surface in soft cast iron can be made beautifully smooth and satisfactorily flat.

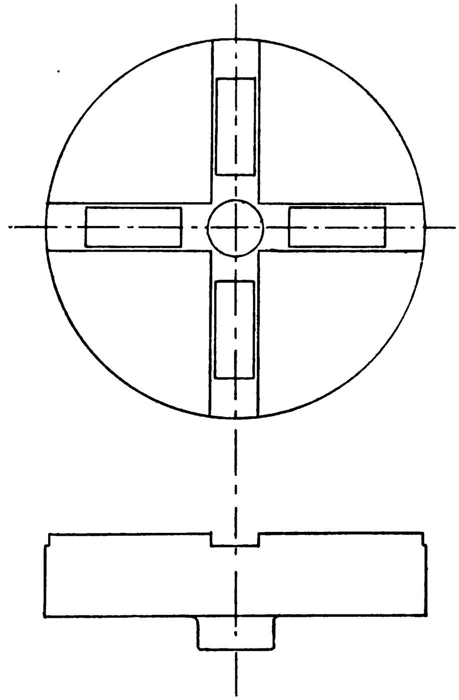


FIG. 113.—Setting out jaw-chuck plate casting.

In slotting the surfaces, a gauge would be necessarily used, and it would be found that, however great the care bestowed, and however good the tools used, a considerable amount of hand-scraping would be necessary to make the surfaces properly smooth, true, and parallel in depth and length. In describing the second type of chuck plate (Fig. 113), there is much that is similar to the first, but the jaws do not fit the slots on their shanks; but by having the sides of the body of each jaw tooled parallel and gauged definitely to a given width, provision is made on the face of the plate by cutting a parallel trench and intersecting this at right angles. Although the jaws have a comparatively shallow seating it is obviously clear that a full control of each jaw will be possible. Now, much depends upon the screws, how the jaw-chuck will finally grip the work, any slack fitting of the screw and nut at the back of the plate will cause the jaw to proportionately leave the plate, and in so doing pull the vertical actuating screw out of its proper alignment.

TURNING AND FITTING IN THE JAWS

The steel forgings are generally hammered out of solid in preference to welding on the shanks. Each forging is struck and "sounded," and examined carefully before any setting out is done, after this they are placed in turn on the marking-out table and packed so that the shank lies evenly with the line of the table, and the inner face AB

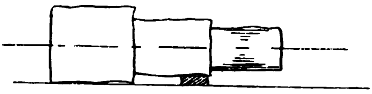


FIG. 114.

approximately true to a square (Fig. 115). The surface gauge is used in running a line all round the forging, each jaw being similarly treated; they are next turned over, packed as before, and a second line made. The jaws are then turned on their sides, bringing the scribed lines into the vertical plane, and lines are drawn intersecting the previous ones.

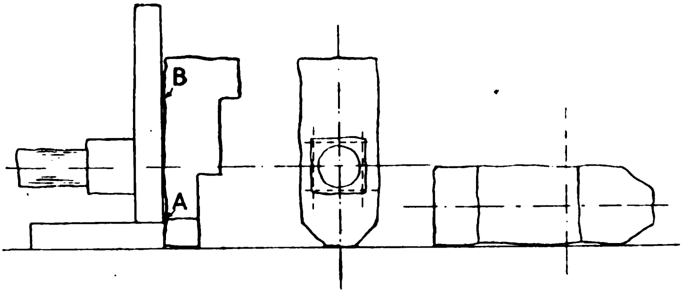


FIG. 115.—Setting out steel jaws for chuck plate.

The mean of the lines is the true centre of each jaw, and a prick punch is used on both centres, the holes being enlarged with a centre punch, and afterwards square-centred, or a "slocomb" drill used direct.

After thus centring, each jaw is faced on AB and the tool set for marking off the distance to end, the actual width of the chuck plate.

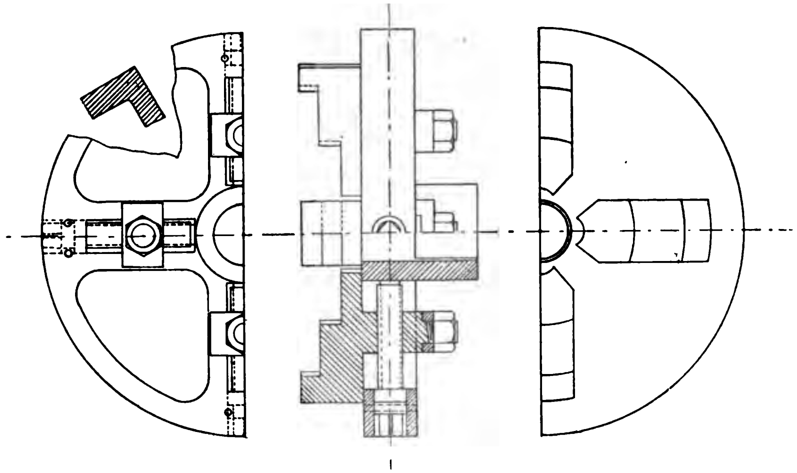


FIG. 116.—Views of lathe jaw-chuck finished.

The surplus metal can now be removed, and the diameter turned. Now since the jaws are finally to be a sliding fit in the chuck plate, the actual width of the slot will be gauged, and the shape of the rectangular part of the jaw lined out, as in Fig. 115. A small deduction is allowed on these dimensions, so that when the shanks of the jaws are turned and milled, the corners will finally show the tool marks. Straddle mills will be used in tooling the sides. Machined in this manner the jaws will be alike to gauge, however many sets are tooled. The ends will be next reduced and screw-cut for the retaining nuts. To prevent seizing, or holding the jaws from sliding easily, it is essential for the washer when gripped by its nut to press fairly on the jaw-shank, and at the same time to simply touch the plate. There must be no shake, and to keep the parts in correct position, the nuts are made a tight fit on their respective screws. It must be understood that this part of the mechanism is of vital importance for the subsequent use of the chuck, but it is *never* to be touched, unless it is found necessary to repair some other working part.

After the jaws are fitted to the plate and secured, the whole are mounted on a steel mandrel and turned up. When, however, the jaw-chuck is for a new lathe, the plate may be screw-cut to its own spindle nose, and then the jaws may be turned in place. This obviously ensures the final true running of the plate, but for precise working the jaws are hardened and ground.

In practice an additional set of jaws are frequently supplied; these, being quite soft, do no damage to those pieces of work which have to be gripped and ground after hardening. Fig. 116 shows views of a complete chuck.

MAGNETIC CHUCKS

A very useful type of chuck is illustrated in Figs. 116A, B, and C—a magnetic chuck made by H. M. Budgett, Chelmsford. These chucks are designed to hold small parts having sufficient area. Given the body of a chuck wound with a given quantity of wire, a definite number of

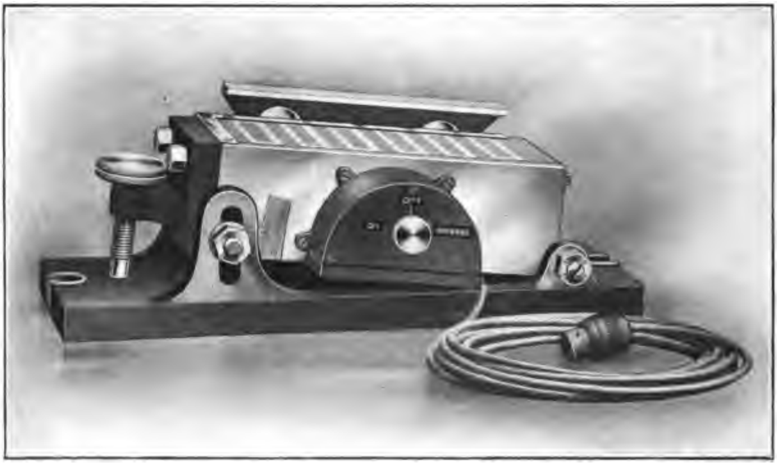


FIG. 116A.—Magnetic chuck.

lines of magnetic force are produced. This magnetism is distributed over the face, and the intensity of the holding power depends upon the form of face, and how much it is split up by the white metal. Thus a very powerful chuck is produced by fitting a simple face as illustrated.

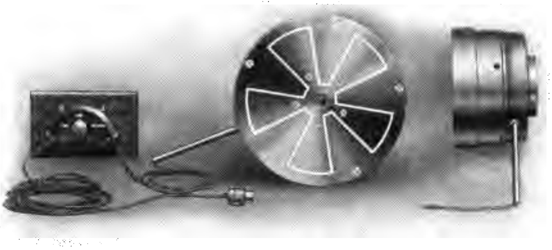


FIG. 116B.—Magnetic chuck for lathe work.

Such a face will exert a pull of 100 lbs. per inch of white metal on a steel plate of sufficient thickness to carry the magnetism.

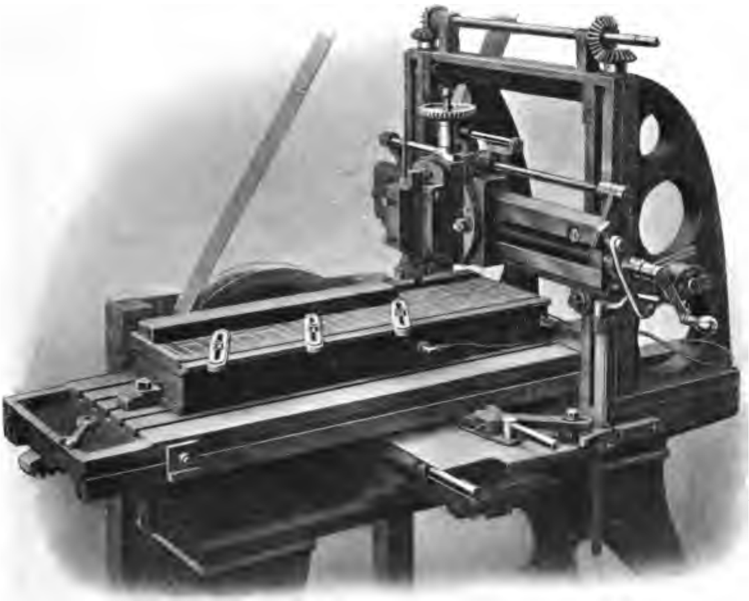


FIG. 116C.—Magnetic chuck holding work on planing machine.

The average pull may be taken to be between 40 and 60 lbs. per inch, this being sufficient to hold ordinary work, such as washers, strips, etc., for grinding or light machining. Even for light machining it is advisable to provide some further stops or other device for preventing the work sliding over the face. For this purpose projecting studs or rings are often fastened to the face. Much less force is of course required to cause the work to slide than to pull away from its face. About 10 lbs. tangential pull per inch will cause the work to slide.

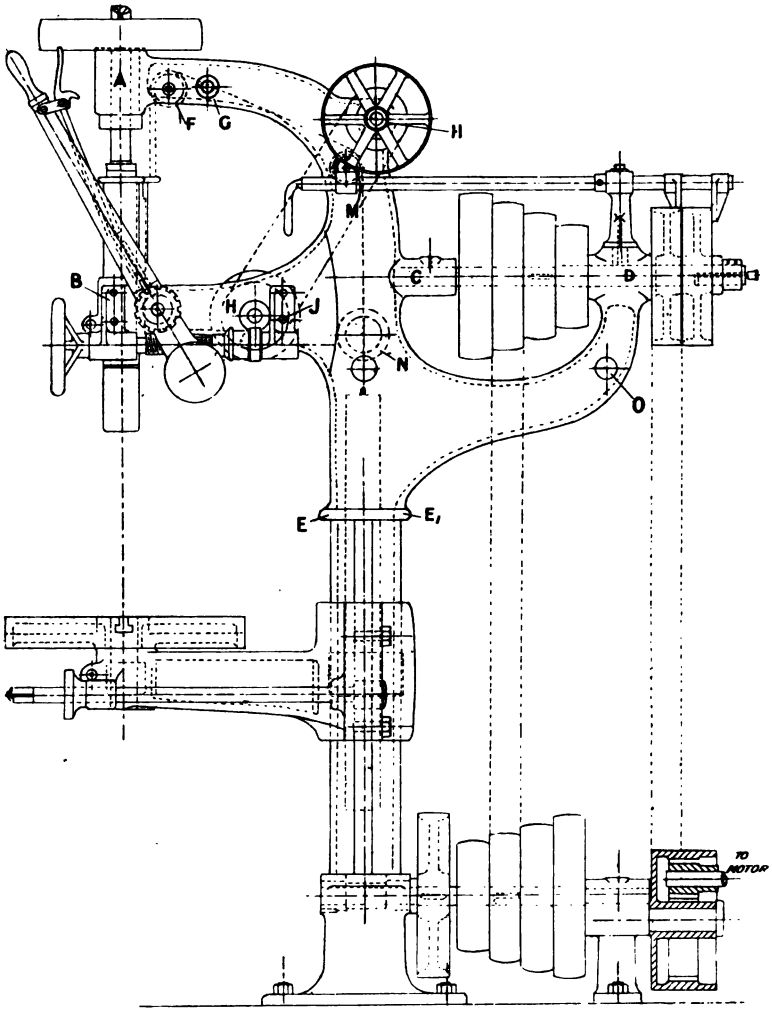


FIG. 117.—Vertical drilling machine, motor driven.

It must be clearly understood that there are limits to which work can be held magnetically, therefore these chucks are not suitable for heavy cuts, either in grinding or machining, except in cases where a large area of the work comes into perfect contact with the face of the chuck.

It is difficult to give tables of the depth of cut and rate of feed, as this must vary with the size and thickness of the work. Thus a very thin steel washer, say $\frac{1}{32}$ in. thick, cannot be held strongly, as the thickness is not sufficient to allow many lines of force to pass, and the steel is magnetized to saturation. Great care has to be exercised in grinding these even with light cuts. Parallel strips and similar work may be machined at 30 ft. per minute with a $\frac{1}{16}$-in. cut and $\frac{1}{6}$-in. feed.

ADVANCED EXAMPLE OF MARKING OFF

In Fig. 117 a sectional elevation of a motor-driven drilling machine is given. The body which is to be marked off for boring may be cast to the pillar, or it may be jointed at EE_1. When the pillar, body, and foot are combined in one casting, it is found difficult to obtain parallelism between the pillar and the spindle bearings. It is therefore much more expedient to do the work as shown in Fig. 118, which represents the body cast as a detached part. The cardinal points are the lines AB relative to the lines CD and the base line EE_1. These lines cannot be varied much, because the smallest change at E_1 greatly alters the points A and D (Fig. 118A). Similarly a small change at E, materially throws B and D out of true position. The amount by which any point may be shifted is therefore a minute quantity.

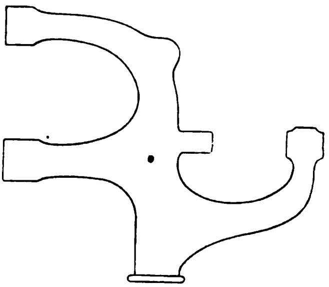


FIG. 118.—Drilling machine body. To be marked out and machined.

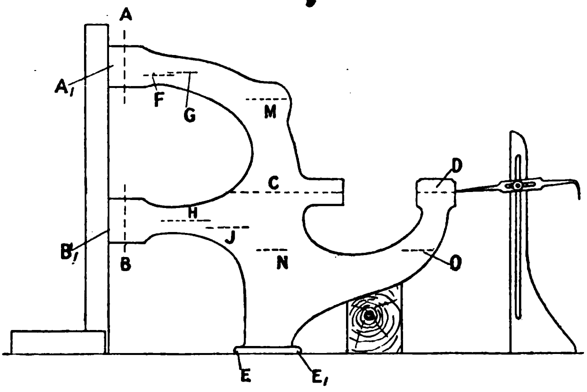


FIG. 118A.—Marking out drilling machine body.

It is, however, still the practice to insert cores in comparatively small holes, such as for the spindle bearings; these will require special attention, although it must be stated that there is usually enough to be done with the other points without being compelled to give this part of the work a special consideration. There is, for instance, the production of the line AB truly at a right angles with the line CD, apart from noting the general contour of the casting. It is expected that AB will be parallel to A_1B_1, but such is very unusual, the casting generally being a little warped. In principle there can be no deviation in setting out whatever the irregularities or errors in the work may be. Therefore to avoid these troubles as far as practicable, the patterns should be made in a manner and of a material that will retain a permanent form. Undoubtedly iron patterns are the best, but to obtain these in a perfectly smooth and suitable form for moulding is attended with considerable labour and expense.

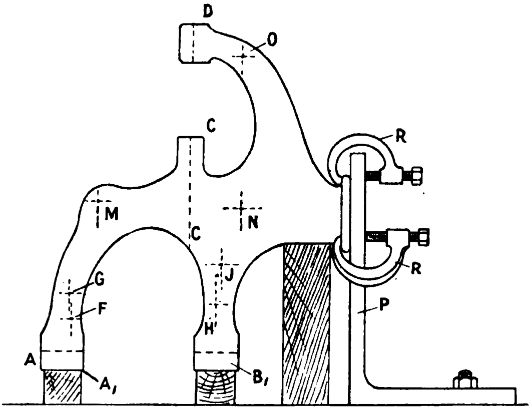


FIG. 119.—Marking out drilling machine body

Referring to the above example, it will be seen that there are many other positions to be marked off as E, F, G, H, etc., but these are all relative to AB, CD. The great usefulness of a stout angle plate P and cramps R, R for supporting the work during the marking off stages is well shown in Fig. 119.

SETTING OUT BRACKET

A bracket requiring considerable care in setting out is shown in Fig. 120. The bearing at the top of the vertical casting is of the cap and block type. This is to give support to a horizontal shaft. From the centre E to the holes A, A is a longer distance than usual, but to give ample support the surface S is made broad and deep. The surfaces S and T being parallel, but on opposite sides, are planed first, and the casting is ready for marking off the positions for the holes A, A, A_1, A_1, and B, B. While thus fixed the surface at joint F can also be marked. In this way the wall sides of BB will be perpendicular, and the seating S truly straight. To facilitate the holding the bracket is secured to an angle plate as in Fig. 119. The subsequent placing of the casting for machining is decided by the form of brasses used. The brasses may be bored in place after fitting, or they may fit in a bored seating in the bracket, in which case the brasses are bored, and turned upon a mandrel. Whichever plan is adopted the true alignment of the shaft can only be obtained when the above surfaces are carefully set to the markings and secured without any springing.

While the broad surface S gives ample room for fixing an angle plate, the surface T can be used to verify the setting, while the hole for the shaft E or the brasses are bored. The surface T is to act as a seating for a further bracket. The reader must understand that after much use angle plates are frequently found distorted, and it should be a general practice to thoroughly overhaul the condition of an angle plate after it has been secured but before any work is fixed to it.

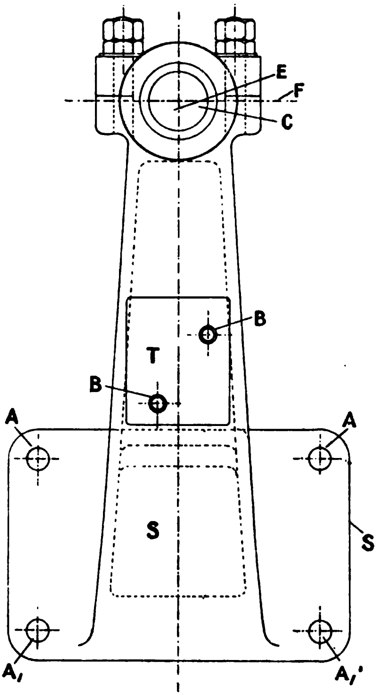


Fig. 120.—Setting out large bracket. (Front elevation.)

Sometimes burrs near the slots are the cause of an uneven setting, these should be removed and the plate tested with a reliable square.

Angle Plate Work in the Lathe

The work, whenever it is practicable, should be secured approximately in position on the angle plate, and then the final setting can be done by moving the angle plate about the face plate until the work centre revolves truly. The setting for tooling of angle plate work is only resorted to when other means are not convenient, *i.e.* the time occupied in this kind of fixing and tooling pieces in the lathe is more than that required when the pieces can be directly secured to the face plate.

This will at once be obvious, that however small the angle plate may be in dimensions, there will be an amount of overhang of plate and work, and usually a counter weight required to balance the load. The greater the distance the work hangs from the centre, and the further it is from the face plate, the less forcive should be any external tooling feed. Or, when boring and screwing internal surfaces the greater must be the care in tooling, just proportionately as the distance the work is from the plate. Pieces of work requiring an extended table for support, or which are not very deep from the base to line of centre may be held on the outer surface of the angle plate, without causing much inconvenience. It is when the gap has to be made in the lathe bed by the removal of the bridge piece, to admit a large face plate, that the angle plate and its work become troublesome, and more or less dangerous, if a fair speed is run without the gearing. The *perfect* balancing of the plate is seldom obtained, and as a consequence there is an unequal strain on the bearings, especially at the front neck when heavy work is done.

For these reasons the nearer to the lathe centre the plate supporting the work can be placed, the smaller will be the balance weight and the less the danger, because of there being less centrifugal force acting on the parts concerned. Speaking generally, angle plates are planed on two surfaces, *i.e.* their outer or adjacent sides, the inner corners are angled or filleted, while those of the larger type are ribbed at intervals. By having a stouter pattern and a fillet at the inner corner, the plate may be tooled all over, rendering it usable on external and internal faces.

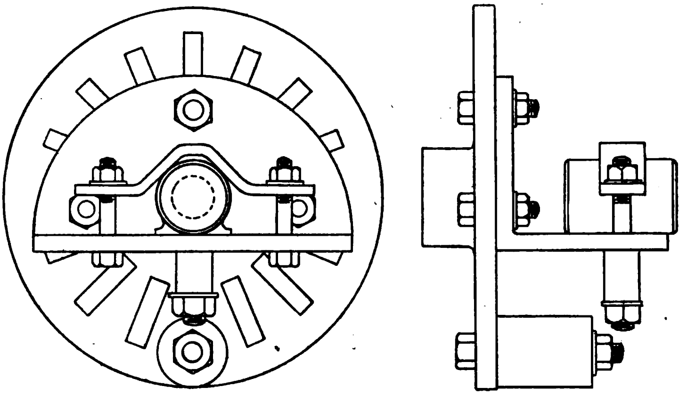
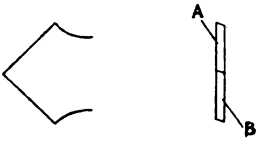


FIG. 121.—Bearing set on angle plate for boring.

An example of the usefulness of a plate of the above description is given in Fig. 121, which illustrates a lathe-face plate carrying an angle plate with a piece of work to be bored, this plate by being fixed in the position shown has no overhanging part, and obviously could accommodate work of much larger dimensions without any parts projecting beyond the rim or the face plate.

Similar work placed on the external face of the plate would have a considerable extension beyond the lathe plate rim, necessitating the removal of the lathe bridge; if not a much larger face plate on which to ride would be substituted.

Smaller pieces, such as general brassfinishers' work held in the above manner shown, can be secured and revolved at a high speed with the vibrations reduced to a minimum. The usual practice for all repetitionary work is to use a turret for the drills and tools, but where this is not convenient a drill rest and drills are used as shown in Fig. 122.



Flat drill, cutting edges.

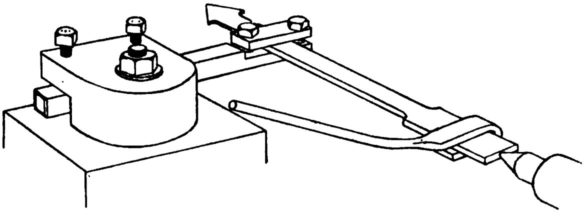


FIG. 122.—Method of holding flat drill.

There is a great deal of work which can be carried on a swivelling angle plate while it is drilled, milled, or shaped. Fig. 123 shows how a machine strip can be tooled to an angle of 60° by simply setting the plate to the degree indicated. The angle plate may then be swivelled

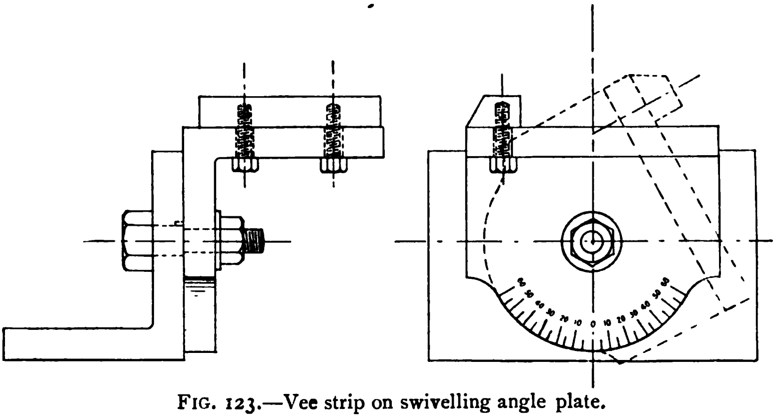


FIG. 123.—Vee strip on swivelling angle plate.

to bring the upper face parallel with the cutter spindle, in this case two surfaces can be tooled over, either together or separately.

When quantities of similar angular pieces are required they may be held conveniently on a supplementary table, and milled on three faces with gang mills.

SETTING OUT AND TOOLING ENGINE ECCENTRICS

Engine eccentrics are used to convert rotary motion into reciprocating motion, that is from the crank shaft to the slide valve rod. A small eccentric fitted to its shaft is given in Fig. 124. The sheave is the eccentric proper, marked A, and the straps to which the rod is attached is marked B.

The sheaves are of two forms, solid, or in two parts. Solid sheaves are always adopted where it is convenient to pass the sheave over the end of the shaft. The material is usually cast iron, but in some types cast steel or forged steel is used for the straps. Some high-speed engines have gun-metal eccentric straps working on a cast-iron sheave. An illustration of an eccentric and sheave is given in Figs. 124, 125, 125A. In marking out, the sheave is first plugged with wood, and the two centres struck and centred. From these centres the diameter of the bore is described, and the outer diameter respectively. The latter, however, is unnecessary when once a casting has been machined from the pattern. In the above example the sheave is mounted in the jaw

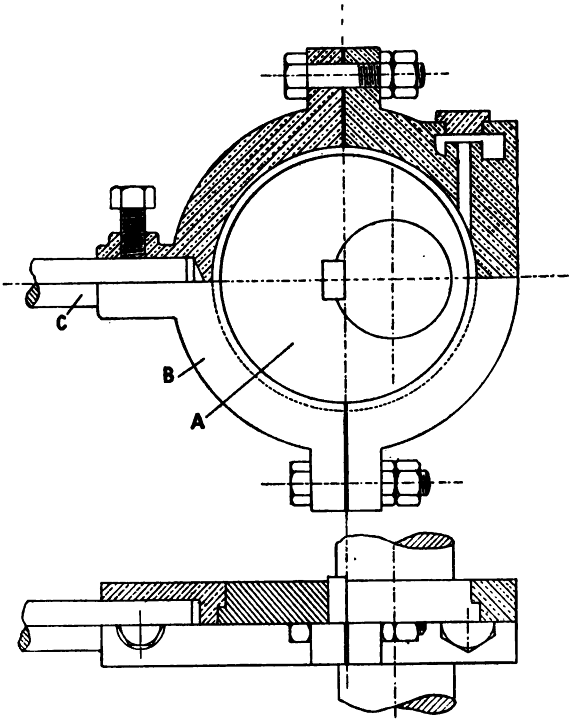


FIG. 124.—Small eccentric.

chuck for boring. Where the jaw chuck will not admit the work, a face plate and parallel strips will be used. A larger eccentric could be partly faced on each side of the bore before removal, this would save time of re-fixing.

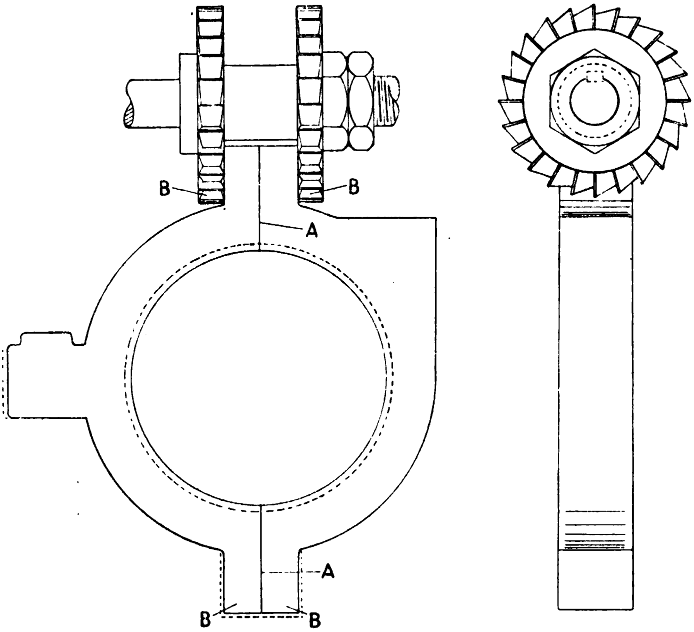


FIG. 125.—Straddle mills. Tooling eccentric straps.

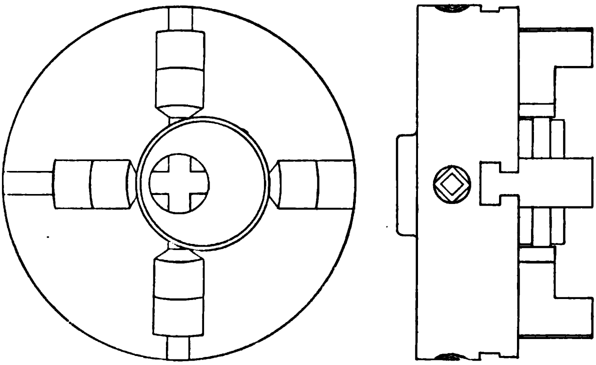


FIG. 125A.—Boring eccentric sheave in chuck.

To turn the sheave an eccentric mandrel is used. The sides of the work may be tooled concentric with the bore, and the top and shoulders tooled while mounted on the eccentric centres. A pair of gauges for width of the eccentric and depth of the shoulders should be filed up from a strip of thin steel. These will greatly assist the progress, and save repeated trial of the calipers. An ordinary depth gauge in the hands of an expert will suffice, the width of the top being obtained from a caliper or caliper gauge. The straps will be milled at AB, and may be sweated together or secured by their turned and fitted bolts. Fig. 125 shows the straddle milling cutters operating on the seatings for the bolts and nuts. In fixing these for boring, a face plate and parallel strips will be employed. The shoulders will be bored first, and the recess tooled carefully to the gauges, the surfaces being finally scraped and polished, the same kind of care being bestowed on the sheave.

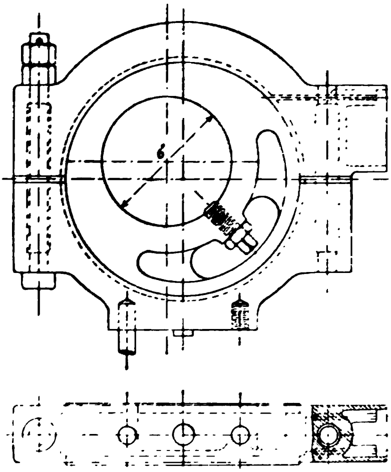


FIG. 125B.—Eccentric and straps.

In the eccentrics used on locomotives, there is an antifriction liner between the sheave and straps. These serve a very useful purpose; they may be tooled at a very high speed and may be stocked for renewals at little cost.

In Fig. 125B, a larger type than Fig. 124 is given, but the sheave is still in one part, and is not keyed, but retained by a set screw. The advantage of the set screw is that the true position of the eccentric may be located before any cutting is done in the shaft. The screw is finally kept in position by the lock nut shown.

USES OF HAND TURNING TOOLS

The art of hand turning in metals is much less practised now than in the days prior to the introduction of special stud and screw making machines, or other special forms of the lathe. Hand turning, however, is still in demand in the tool room, and in the millwright's shop, also in the engineer's workshops, where they do not yet do all their work on special or modern lines of repetition. There is little resemblance in the tools used to turn iron and steel with those used at the brass turning lathe, while in the manipulation of the tools, there is scarcely anything in common. The hand tools for turning wrought iron and mild steel take a decided bearing on the lathe rest, and in no case should be allowed to overhang, since the downward force of the work as it rotates would take the cutting edge of the tool with it. Therefore, to counteract this, each tool is made with a sharp heel, which must take a firm seating on the lathe rest, while the cutting edge is in operation. Imitating this principle, the slide rest is the outcome, it being absolutely rigid under any load. In hand tooling the operative, while firmly grasping the tool handle, almost imperceptibly moves his wrists steadily guiding the depth of cut and the rate of feed. Meanwhile the heel of the tool is practically stationary. The extreme end of the tool handle is also made to help in controlling the cutting edge, and in steadying the whole movement to the right or left or to put on an increased pressure when the diameter of the work requires a considerable amount of reduction. The chief hand tool is the graver, shown at A in Fig. 126. This tool has two cutting edges and two heels, the edge is of diamond shape, being ground to an angle of 45°. With this tool alone an expert will make a stud in a few minutes, then chase it to fit a nut satisfactorily, striking the screw thread with the graver.

There are four other principal tools, the triangular or side tool, D, chiefly used for facing and cornering; the round nose, C, for radius working; the square nose, B, for smoothing; and the parting tool, E, for grooving or cutting off. The above are as small a set as is practicable, but each may be made in duplicate, or there may be tools of similar outline but of reduced sizes for small work. Cast iron can be finished and smoothened much better by hand-scraping, in a similar manner to the larger work done in the power lathes; indeed the same tools are used, but of smaller dimensions. To improve the appearance, and facilitate the working, the tools are frequently re-ground and stoned.

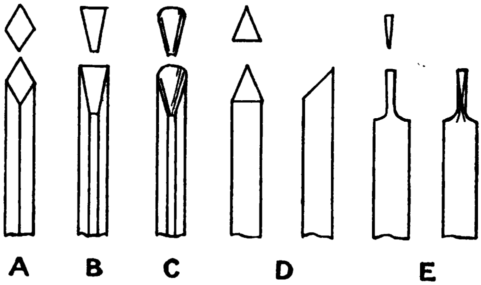


FIG. 126.—Hand turning tools for iron and steel.

Anvil-made forgings, which are more or less irregular after facing and centring, are sprung or hammered until satisfactorily straight. The hammering should be done over the mandrel block or some similar casting having a suitable core. Before commencing to use the cutting tools, the necessary gauges or templets should be at hand, unless it is that the piece of work into which the object to be turned and fitted is portable. In any case the various diameters and lengths should be overhauled and the forging compared. After this, the largest diameters are roughed out and the shoulders for the approximate length turned down. When one half has thus been tooled over, the carrier is put on the opposite end, and the work reversed between the lathe centres.

No attempt at finishing should be made until all the shoulders are defined and cleared; following this the larger diameters of the work may be finished and carefully gauged over. Many lathemen are unfamiliar with the use and possibilities of hand turning tools, but in some of the leading shops in Lancashire and Yorkshire the art of hand turning is still fully appreciated and adopted. The operatives become experts at the work.

"Roughing out" Turning Tools

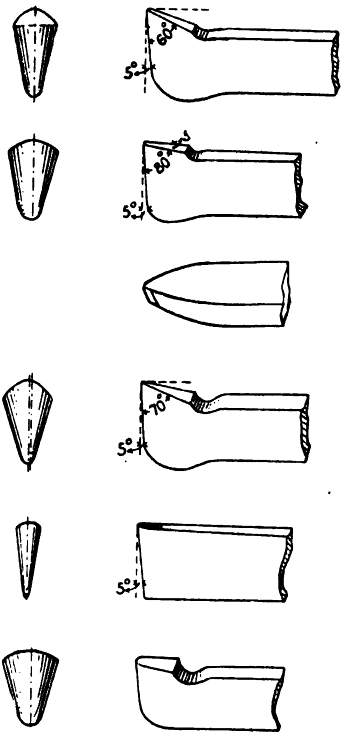
Power lathe cutting tools, operating on the heaviest class of work, are usually forged from solid bars of steel, the section of the bars vary according to the depth of cut and rate of feed required. Some of these tools are 6 in. on the cutting face, and for that reason solid tools are the most rigid. All cutting tools, however, should have a decided "leading side," the lead being in the direction of the traverse, the front angle of the tool is very small, sometimes this is called "angle of relief" and may be just 3°. The top face of the tool is straight for turning the hardest iron, such as chilled rolls, and sometimes it has been found advantageous to grind this down (outwards) really giving a negative angle, which obviously destroys all possibility of cutting, but it gives increased backing to the tool edge, thus enabling it to penetrate the hard surface of the roll, if only to very slowly scrape, instead of cut it.

Such tools cannot be fed transversely to the work by the customary saddle screw, but are fitted in a large rest which is made to advance only when the slide is driven forward by means of stout iron wedges which are struck with a sledge. As the material to be cut is less hard, the cutting tools gradually receive a top angle. Thus, cast iron can be satisfactorily cut with tools formed to an angle of 70° to 80°; therefore, the softer the iron the keener or more acute the cutting angle may be. Annealed cast tool steel will be satisfactory if cut with tools at 70° to 75°, and soft mild steel will yield readily with tools at an angle of 65°. Soft iron, well lubricated, will cut well with the last-named tool, but the best soft iron curls readily with tools ground to 60° or even less. There is a mistaken notion to make the tool more acute by increasing the front angle, the cutting is actually done at the edge, and the greater the amount taken from the top the more the penetrating power of the tool.

There must for heavy cutting always be a good stiff backing to the cutting tool's edge to carry away the heat as it is generated. This is especially the case when turning or planing heavy cuts in cast iron, where, of course, a lubricant is not used.

Now, while it is proper to give a lead or top rake for ease in penetration, no attempt need be made to get curling shavings from this material unless it is specially soft, therefore with a cutting tool having an angle of 80°, 5° may be for side clearance and 5° for top rake, the front angle always being as small as possible. "Double duty" should not be attempted from the same tool, indeed it is scarcely necessary, as the work may be reversed if it is lathe work, while planes generally carry two cutting tools bolted to independent slides (see Fig. 127).

The attacking side of the tool edge can be made with an almost straight wall, curving off gradually towards the tool nose, which should be nearly flat so as to leave a face on the work comparatively free from ridges. This has a further advantage, since so little actual cutting takes place at the tool nose the life of the tool is increased. Contrasted with this, a tool cutting edge may have a considerable wider range of surface in contact, and, as a consequence, more friction will be set up, and since the tool nose proper has more work to do, the actual cutting power or endurance of the tool will be diminished; besides this, a broad tool has little power of penetration. A further example of this occurs in using a knife tool for deep cutting (Fig. 128), the blade of which is a perfect cutting tool, but the point has absolutely no power to cut, therefore the point is the first to give way. It may be mentioned, however, that by rounding the point a little the above defect is overcome to a considerable extent.



Roughing out tool for wrought iron.

Roughing out tool for hard cast iron.

Roughing out tool for brass turning.

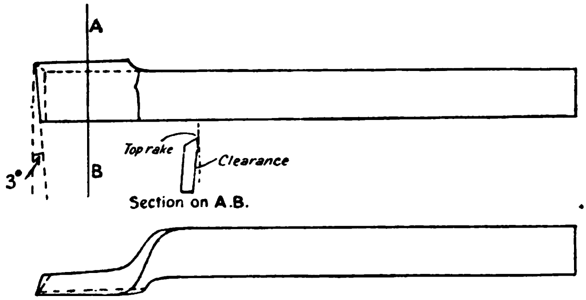
Roughing out tool for mild steel.

Roughing tool for cast iron, taper drawn.

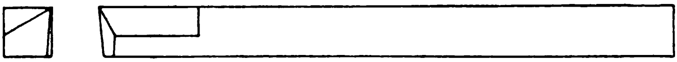
Broad-nosed roughing tool.

FIG. 127.

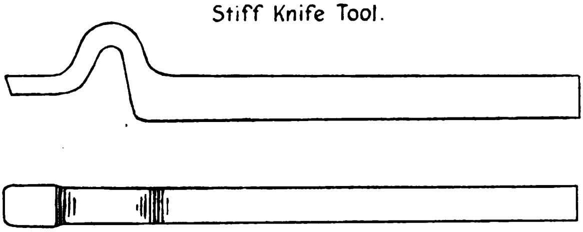
The tool of which kind there are the most in general use is the "sliding and surfacing tool." This varies in angle, form, and strength according to the purpose required (Fig. 127). Objects which are to be finished a true plane, or a rectangular figure, may be roughed out on top and sides with a front tool, and a right- and left-hand crank tool respectively; or a tool holder, having a swivelling arrangement by which one tool can be used on the three surfaces. This also applies to curvilinear work and external surface work in the lathe, such as shafts and rods between the centres of the lathe, face plate and chuck work generally. The tools may be forged with a hook to allow steel shavings plenty of room to clear themselves, or with a flat under surface if intended to operate on cast iron, or on brass, bronze, etc., in which cases shavings are not desired to coil (see Fig. 127).



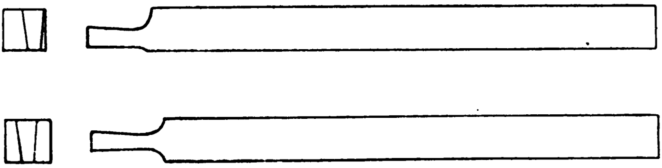
Knife Tools.



Stiff Knife Tool.



Spring Tool



Parting Tools

FIG. 128.—Power lathe turning tools.

The shape of the tool is taper for alloys, because strength is not usually required, neither very much cutting surface at the tool nose. Whatever the shape and strength of a front tool, the same applies to the right- and left-hand crank tools, in fact, the latter are forged quite the same until bending for one side or the other. This tool is known for its purpose, rather than its shape, as a right-handed crank tool (sometimes called a side tool), and has its cutting edge on the left side, but it is used in surfacing work on the right-hand side and *vice versâ*. The tools used on cast iron have not much top angle, so that with proper grinding the original shape can easily be maintained. This gives a decided help to the use of tool holders of the "Smith and Coventry" swivel type, where the position of the slot is so arranged that when the tool is secured the top angle is correct relative to the work, while actually the top surface is at an equal angle to the body sides, and quite parallel with the base at whatever position the swivel may be.

Wherever it is possible tools of a fixed form and angle should be used. This applies to all machining operations of a general character. High speed steels are now in universal favour, and it is only in the smaller shops where special jobs and repairs are carried out that the operatives have any choice, or even power, to use other than the tools kept for the purpose. It has been clearly proved that a special department set aside for the care of the tools, whether for turning, planing, or milling, is of great benefit to the management, inasmuch as the actual condition of all the cutting tools are known. New tools are given out as required, and faulty tools are put under repair, hardening and tempering and annealing sections being all in the hands of experts, so that each operative or machinist is kept from waiting, since he is at once supplied with the proper tools for any specific piece of work he has in hand. The high-speed steel is now made into all kinds of tools for milling, turning, drilling, reaming, chipping, etc. The sections necessary for the tool holders are also provided, so that the use of tool holders has again revived, thus enabling light lathes to run at a considerably increased speed, while those specially designed for high-speed cutting can be fitted equally with tool holders or stouter tools from the bar. Capstan and turret lathes are usually provided with tool holders, so that high-speed steel can be used in them to advantage. High-speed steel was not at first manufactured in all its original sections, so that the use of special tool holders was limited. Drills and milling cutters were among the first special cutting tools, and following these the steel was forged into the general sizes for all kinds of cutting tools for lathe work, also for planing (see Tool Holders, pp. 124–127).

FINISHING TOOLS

Journal bearings are bored and rounded to a precise form with tools which are a counterpart of those used upon the neck of the shaft on which the brasses or bearings fit. The steel shafts being harder to cut than cast iron, and of a more uniform character, will admit of a high finish being made (see Fig. 128) when the spring tools are well lubricated and kept sharp by means of an oil stone. Spring tools are of a delicate construction and must not be hurried. They should not cut out a radius all at one sweep, but gradually.

It will be obvious that extreme care must be bestowed upon work of this character, and to prevent the tools from "digging" the hook of the tool is filled up with a wooden plug. Such tools are never ground so as to alter their contour, but are sharpened by simply grinding up and subsequently using an oil stone upon their *upper or flat surface.* Treated in this way, the tools will last for a long time, holding up to shape, and working out the curves smoothly. Shafts are frequently rounded off at their ends by the use of special spring tools, having a radius accurately made at the inner side for work carried between the lathe centres and on the opposite side of the tool, when the work is supported by a stay, and the loose headstock dispensed with, in which case the tool is held in the rest parallel with the line of the shafts. Steel screws of "acme" and Vee shape are sometimes finished with a spring tool which operates on both sides, at the same time it is, however, only in first-class lathes, working on good quality steels that this plan can be adopted with success. If there is any sign of the tools "tearing" the metal, it will be found that a smooth surface can only be obtained when cutting the threads on one side at once, and then the tools must be kept sharp and humoured considerably. These tools are a little narrower than the actual space required to be cut out. Generally we may say that the lower the grade of steel the greater the tendency for the cutting tools to dig, consequently the greater is the task of obtaining a satisfactorily smooth surface on the sides of the screw threads.

Brass Finishing Tools

Brass is hand turned and finished by means of a set of tools much resembling the above in shape, but the work being generally of small dimensions, the tools are correspondingly smaller (Fig. 129). Nos. 5 and 6 are used to smoothen or planish the surface of the work, hence

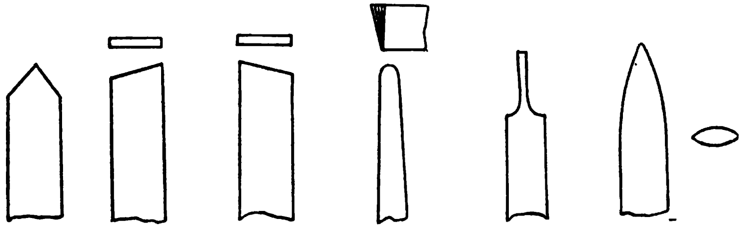


FIG. 129.—Brass hand turning tools.

they are called "planishers." There is, however, always a rough cut taken first by a narrow round-nosed tool, whether turned by hand or when power lathes are employed. There is one important difference in the manipulation of these tools. In the hands of the metal turner overhang of the tool on the rest is *fatal to good work*, and were it attempted chattering would commence and an irregular surface would be produced by this intermittent cutting.

The brass finisher prefers a little overhang, and indeed uses the rest more as a fulcrum, and the long tool handle beneath his right arm acts as the lever enabling him to guide the path of the tool, while his left hand steadies the tool on the edge of the rest. In this manner short surfaces are very quickly roughed out to dimensions and planished, the lathe revolving at a high speed during the operation.

In the power lathe the cutting tool is traversed much as is the case in iron and steel turning, the tool angle always being more obtuse for brass than would be attempted on iron. There are some special alloys which are intended for pump rods, pistons, and other heavy duty work, which are fairly hard and also very tough.

These metals will yield with much keener edged tools, especially when made of the air-hardened class, but owing to the greater endurance and penetrating power of the tools, the traverse (feed) should be reduced.

The effect will be that curling shavings are produced, something like those cut from mild steel. This is seen in some of the alloys of bronze—such as aluminium bronze and manganese bronze. For this class, however, the speed should be reduced a little.

Finishing Tools

Cast-iron plate wheels, which are in frequent demand, can be made bright all over by the use of a spring tool. There is usually a small radius left in the corner, near the boss of such wheels, leading to a flat surface which extends nearly to the rim and then merges into a large radius.

The true shape of the wheel is obtained by having a spring tool prepared with two radii, a little smaller than that of the wheel (see Fig. 128). For example, we may have a plate wheel with radii corners of 1 in. and 2 in. respectively; a suitable spring tool for these will be one having $\frac{7}{8}$ in. and $1\frac{3}{4}$ in. radii: this enables the workman to turn up the boss, and then gradually work the tool by means of the slide rest until the flat part of the wheel is reached. Then traverse along this, up to the next corner, when the tool must be gradually withdrawn.

The blade of the tool being intended to spring or vibrate must not be treated in any way as an ordinary turning tool; its action is really one of scraping and uniformly finishing the surfaces left rough and more or less out of shape by the previous turning tools. This tool, in the hands of a skilled workman, can be used for a long time on similar pieces of work without injury or need of re-grinding, but in unskilled hands it can be the direct cause of spoilt work, or be spoilt itself beyond further use, until it is re-heated and repaired. It is important to note that the *stoutest* tools will "dig" into the surface of the work if made with broad cutting edges and allowed to operate carelessly. Therefore, a spring tool must be used very carefully, because it has a thin blade, and is usually formed to a definite shape.

Gauging the radius will quickly show when a proper amount has been left for the spring tool.

Tool Holders

There are a considerable number of different kinds of tool holders in use, the main idea being to use very short lengths of high-speed steel, usually forged to shape and finished to the desired form and angle by grinding to a gauge. High-speed steel may now be obtained in any required section, so that tools of circular, square, and angular forms may be secured. Whatever the make of holder, the tool should stand well up to its work. To properly effect this the holders are generally made with a short bull head, into which the tool is passed, leaving only the tool nose protruding. The clamping arrangement will swivel, or the tools may be fitted into pockets, the mouth of which points front, and both right and left hand (Tangye type). All such holders are fitted with a retaining

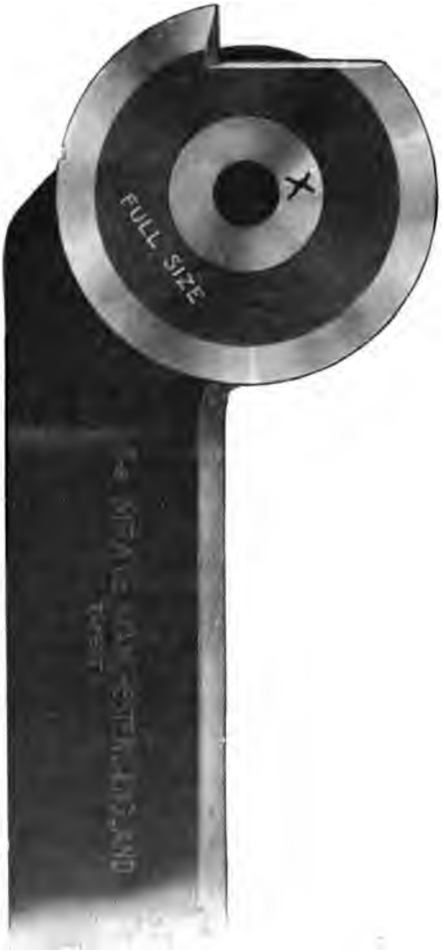


Fig. 130.—Screw-cutting tool.

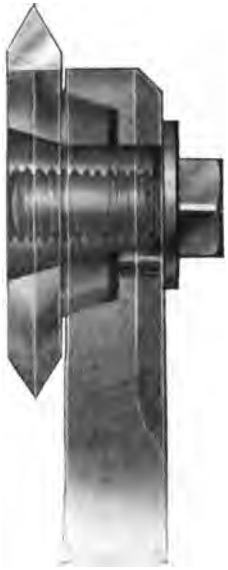


Fig. 130a.—Vee thread-cutting tool.

screw and nut, or with a retaining screw direct on to the side or top of the tool proper.

These screws are of course made hard, but with constant use are distorted, and must occasionally be substituted by new ones. It is, however, when the tapping hole is stripped that trouble begins, and herein lies the one defect of the holder as compared with a solid steel cutting tool. The hole may be re-tapped a larger size and a stouter screw fitted, but there are limitations to this procedure. It may be pointed out that although the holders are adaptable for a large variety of work, there are pieces which cannot be tooled by them conveniently.

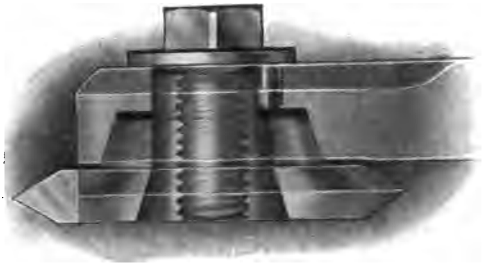


FIG. 130B.—Section of screw-cutting tool attachment.

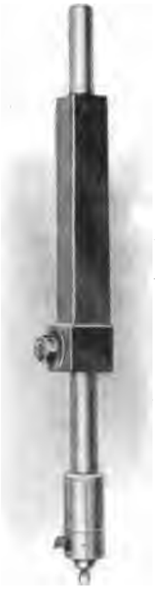


FIG. 131.

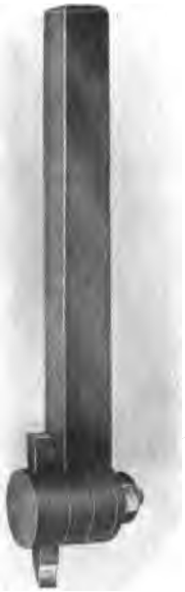


FIG. 131A.—Beeston tool holder.

One of the most economic uses of tool holders is their employment in the turret and capstan lathes, where very small pegs of high-speed steel can be used on repetition work, operating on a great number of pieces without losing any of their cutting power, or in some cases any appreciable dulness of cutting edge.

"BEESTON" TOOL HOLDER

A tool holder, suitable for carrying a slotting tool, is shown in Fig. 131. The bar is telescopic, and is shown with a relief head. Its adaptability can be readily recognised.

By releasing check bolt the bar will slide to any position. The relief head is to preserve the cutting edge of the tool as the bar slides upwards.

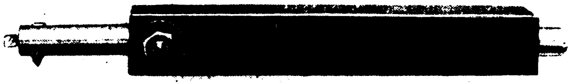


FIG. 131B.

A shaping and planing machine tool holder, constructed to curtail the expenses of valuable high-speed steel, is also shown in Fig. 131A. The tool, when placed in position, will surface and down cut, right and left hand, by rotating the head.

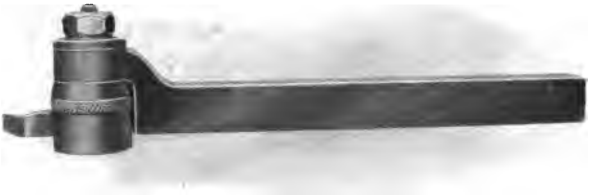


FIG. 131C.—Beeston tool holder.

A lathe boring-tool holder is given in Fig. 131B. The bar is telescopic, and is adapted for all classes of boring and internal cutting. The cutter bar is adjustable to any position by releasing the lock bolt.

A tool holder for general turning is shown in Fig. 131C. The cutting tool may be swivelled into positions suitable for turning on the straight, or for surfacing on the right or left hand, as desired. If the tool nose is too high or too low, then by rotating the milled section the cutting edge can be brought into position as desired. Fig. 131D illustrates self-contained capstan-head tool. A formed disc tool holder is given in 130, A, and B. The tool is for cutting Vee threads, and from the views showing the sectional plan the angle of the tool nose is clear.

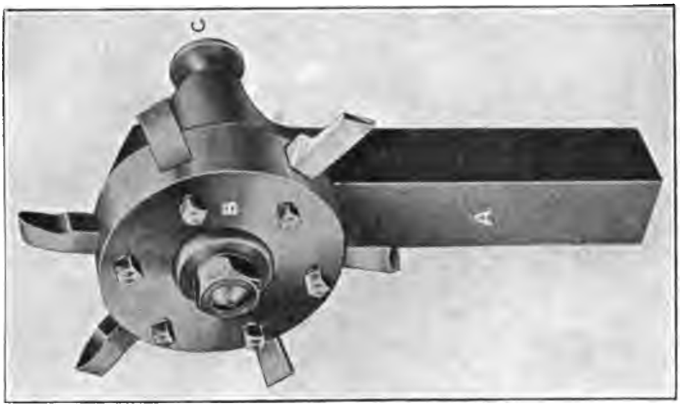


FIG. 131D.—" Capstan "-head tool.

In this arrangement the height as well as the angle is predetermined, so that for a given lathe, when the holder has once been properly located, the tool nose may be re-ground until the whole disc has been used up, but the correct height and angle will remain intact. This is a notable feature made by the Machine Tool Attachments Co.

HAND SCRAPERS USED IN THE LATHE

Scrapers are shown in various forms in Fig. 132; they are usually drawn (forged) out from old smooth files, ground to the required shape, and hardened. If care is exercised in grinding the faces smooth, and the end at right angles to the length, then the tools become reversible, so that a plate wheel may be scraped up on the boss and plate, with the curve in the corner commencing imperceptibly on the boss and extending gradually until it dies away into the flat surface of the plate.

To scrape up the curve beneath the rim, all that is necessary is to reverse the tool and commence at the extremity, gradually working towards the plate; before quite reaching it, however, the cutting should be stopped and recommenced from the surface of the plate, allowing the scraper due time to make a gentle sweep over the curved surface.

This may need repeating several times from both points until there is a uniform blending of the curve into the flat portion of the plate wheel. The cutting action on cast iron should be sweet, free from jars, and chattering; the speed of the lathe as fast as is consistent with the diameter of the work and the temper of the tool; a light cut at a high speed gives better results than a deeper cut at a reduced speed. The tool rest should be stiff, and a strip of leather laid upon it; this serves as a cushion to the scraper, and generally prevents chattering, if the tool is properly made and held. These points are among the causes of badly scraped-up wheels; a thick scraper, too much cutting surface operating at once, hard or unsound metal, hurrying the pace of the tool, scraping without leather, scraping with a tool having a dull edge. A new scraper must be about $\frac{1}{16}$ in. thick at the cutting edge, hardened, and properly sharpened with an oilstone. No. 1 is a round nosed; 2, left-hand radius tool; 3, right-hand, do.; 4, small front with radius; 5, a side and front tool; 6, do.; 7, a Vee groove scraping tool; 8, a hand-wheel topping tool.

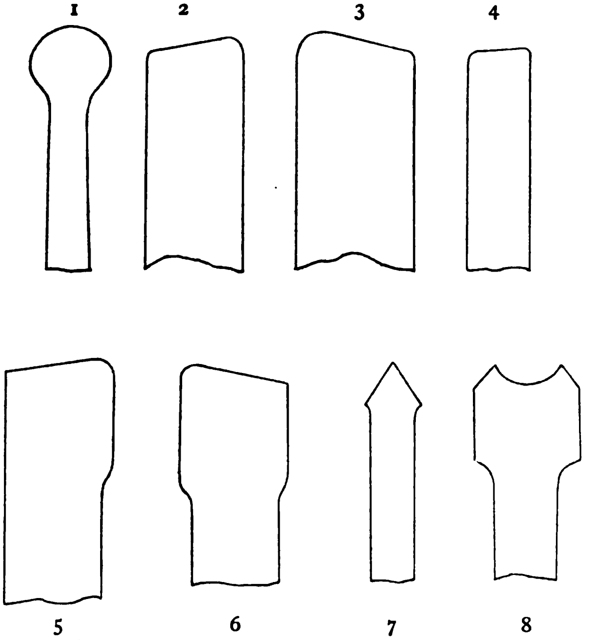


FIG. 132.—Hand scrapers for finishing cast iron.

NOTES ON SCREW-CUTTING TOOLS

In forging tool steel especially, the heat should be imparted very slowly towards the end, not from it, so that time will be given to get the end heated uniformly. After the steel bar has been forged down about $\frac{1}{16}$ in. larger than the finished size, the under side must be ground or filed, so that the bar will lie evenly on any true plane. The tool nose can be roughed out on an emery or carborundum wheel very quickly, leaving just a little to be dressed off with a smooth but sharp file, or grinding wheel in the case of high-speed steel. A sliding caliper gauge or a micrometer can first be set to a little in excess of the actual width the tool is to be finished at the nose. This is to ensure that too much will not be filed or ground away. When the gauge has passed over, it can be re-set to the precise dimensions. The first part to be dressed should be the top angle, which should be at right angles to the thread, and slanting slightly inwards from the tool nose. This is only a small amount, for in grinding the tool quickly loses size; next, the front or relief angle. Following this, the leading side of the tool can be carefully finished to the gauge angle; finally, the trailing side can be reduced just to give clearance to the cutting portion.

Now, while the trailing side of the tool actually is not intended to cut, it frequently receives more dressing than is necessary. This materially weakens the tool. The following or trailing side should not be filed much more than a clearance, or the tool nose will lose much of its support. When the steel is of the air-hardening kind, it must be well annealed before it is shaped. This also applies in any subsequent repairs to the tool. Hardening and tempering a tool of this kind is necessarily a case of good judgment, based on experience. The heating up of the tool nose is done either in a muffle or in the smithy fire. In the muffle the steel may be heated gradually as desired, and without risk of the tool nose burning. Heated in an open fire, the tool is less under control, and may very easily be overheated. When satisfactory, the tool is quenched in water. A bar is next heated and the screw-cutting tool laid on it. This will re-heat the tool and draw the temper. When straw colour appears, the tool is again quenched off.

SQUARE THREAD SCREW-CUTTING TOOLS; OPENING AND CUTTING-OFF TOOLS

To see the colours run, it is usual to brighten the upper surface of the tool after the first cooling.

Various forms and sizes of square thread-cutting tools are given in Fig. 133. Nos. 1, 2, 3, and 4 are for cutting left-hand screws, Nos. 6, 7, 8, and 9 are for right-hand screws. The reason for forming the tool on one side is to enable the screw to commence, or terminate, close up to a shoulder without the body or shank of the tool interfering or in any way colliding with such shoulder or collar. Nos. 4, 5, and 6 are sometimes used as opening tools, just preceding the proper finishing tools. By this plan deeper cuts may be taken by the opening tools, and the finishing tool may have just a small cut operating on both sides of the space previously cut. The saddle screw will be fed very slowly, but actually the time occupied in cutting the screw complete will be less than were the screw to be cut and finished with a single tool. The top rake or tool angle should be slightly from the horizontal, otherwise, as the tool gets dull and re-ground, the whole width will very quickly become less than the space requires, whereas by having very little top rake the diminution is much more gradual. Consequently, the life of the tool is increased. Tools made thus may have an increased front rake or relief angle, without weakening the cutting edge. Nos. 10 and 11 show two forms of cutting-off tools. No. 10 is dressed into shape for a portion of its length; the remaining stock will serve for a second tool should the first one fail. This applies to Nos. 1, 2, and 3; also to Nos. 7, 8, and 9. In point of fact, it is better to harden and temper tools made in this way than is the case in Nos. 4 and 6; the body holding the heat will not allow it to enter the reduced portion so gradually as in cases 9 and 10 respectively; here the larger stock need not be heated up. For instance, if No. 1 is $\frac{1}{8}$ in. wide at the cutting nose, and $\frac{3}{8}$ in. wide immediately behind it, then, when the tool requires renewing, it may be satisfactorily done without additional forging; the surplus metal may be filed or ground to shape ready for a final dressing and setting to gauge.

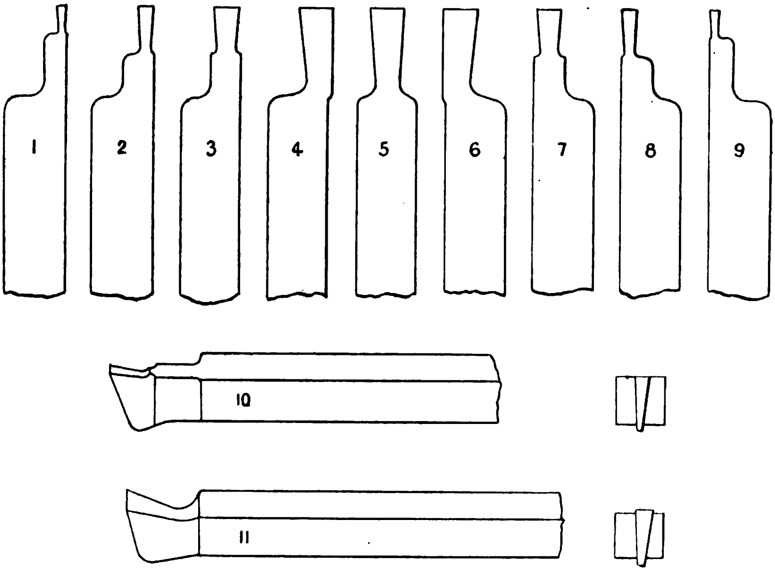


FIG. 133.—Square thread screw-cutting tools.

The proportions in the tools shown, Nos. 1, 2, 8, and 9, are about correct.

SCREWS AND SCREW CUTTING

Screws are of two principal kinds, the Vee, and the square-threaded screw. Vee threads are again divided, as British Standard, or Whitworth screw threads, and "gas," or fine threads. All screws are now standardised, that is to say, for a shaft and a pipe of a given diameter there will be a definite number of threads per inch for the shaft and for the pipe respectively (Fig. 134). We also have the standard square threads, which are all known to have half the number of Vee threads per inch for similar diameters. There is also a thread known by its form and not by its diameter, viz. the "Buttress" thread.

British Standard Whitworth Screw Threads. [Fig. 134.

1	2	3	4	5	6	7
Full diameter.	No. of threads per inch.	Pitch.	Standard depth of thread.	Effective diameter.	Core diameter.	Cross sectional area at bottom of thread.
In.		In.	In.	In.	In.	Sq. in.
¼ (·25)	20	·0500	·0320	·2180	·1860	·0272
$\frac{5}{16}$ (·3125)	18	·0556	·0356	·2769	·2414	·0458
⅜ (·375)	16	·0625	·0400	·3350	·2950	·0683
$\frac{7}{16}$ (·4375)	14	·0714	·0457	·3918	·3460	·0940
½ (·5)	12	·0833	·0534	·4466	·3933	·1215
$\frac{9}{16}$ (·5625)	12	·0833	·0534	·5091	·4558	·1632
⅝ (·625)	11	·0909	·0582	·5668	·5086	·2032
$\frac{11}{16}$ (·6875)	11	·0909	·0582	·6293	·5711	·2562
¾ (·75)	10	·1000	·0640	·6860	·6219	·3038
$\frac{13}{16}$ (·8125)	10	·1000	·0640	·7485	·6844	·3679
⅞ (·875)	9	·1111	·0711	·8039	·7327	·4216
1	8	·1250	·0800	·9200	·8399	·5540
1⅛ (1·125)	7	·1429	·0915	1·0335	·9420	·6969
1¼ (1·25)	7	·1429	·0915	1·1585	1·0670	·8942
1⅜ (1·375)	6	·1667	·1067	1·2683	1·1616	1·0597
1½ (1·5)	6	·1667	·1067	1·3933	1·2866	1·3001
1⅝ (1·625)	5	·2000	·1281	1·4969	1·3689	1·4718
1¾ (1·75)	5	·2000	·1281	1·6219	1·4939	1·7528
2	4·5	·2222	·1423	1·8577	1·7154	2·3111
2¼ (2·25)	4	·2500	·1601	2·0899	1·9298	2·9249
2½ (2·5)	4	·2500	·1601	2·3399	2·1798	3·7318
2¾ (2·75)	3·5	·2857	·1830	2·5677	2·3841	4·4641
3	3·5	·2857	·1830	2·8170	2·6341	5·4496
3¼ (3·25)	3·25	·3077	·1970	3·0530	2·8560	6·4063
3½ (3·5)	3·25	·3077	·1970	3·3030	3·1060	7·5769
3¾ (3·75)	3	·3333	·2134	3·5366	3·3231	8·6732
4	3	·3333	·2134	3·7866	3·5731	10·0272
4½ (4·5)	2·875	·3478	·2227	4·2773	4·0546	12·9118
5	2·75	·3636	·2328	4·7672	4·5343	16·1477
5½ (5·5)	2·625	·3810	·2439	5·2561	5·0121	19·7301
6	2·5	·4000	·2561	5·7439	5·4877	23·6521

There is a thread combining the square and the Vee, *i.e.* a special form called the "Acme"; this thread is flat on both top and bottom, but its angle is 29°.

Another and more recent form of screw thread for very fine and small screws is the British Association thread, known as the B.A. Standard (Fig. 135). It is very important to state the kind of thread required for a given shaft if the diameter is over 1½ in.

Generally speaking, the screws over $1\frac{1}{2}$ in. are made with square threads, unless they are for special work, such as the guide screw of a lathe, in which case the thread will be usually made 29°, or "Acme," screw thread. Commercially, screws are made to definite lengths of

THE BRITISH ASSOCIATION SCREW THREADS. [FIG. 135.

B.A. sizes.	Diameter in inches.	Clearing drill.		Core diameter in inches.	Tapping drill. Nearest number in Stubbs' gauge.	MM. sizes.	Pitch.	
		Nearest number in Stubbs' gauge.	Nearest in inches.				In inches.	In mm.
0	·236	B	$\frac{1}{4}$	·1887	11	6·0	·0398	1·0
1	·209	3	$\frac{7}{32}$	·1665	18	5·3	·0358	·9
2	·185	12	$\frac{3}{16}$	·1467	25	4·7	·0318	·81
3	·161	19	$\frac{5}{32}$	·1266	30	4·1	·0287	·73
4	·142	26	$\frac{9}{64}$	·1108	33	3·6	·026	·66
5	·126	29	$\frac{1}{8}$	·0981	39	3·2	·0232	·59
6	·110	32	$\frac{7}{64}$	·0849	44	2·8	·0205	·53
7	·098	37	$\frac{3}{32}$	·0753	47	2·5	·0188	·48
8	·0866	42	$\frac{11}{128}$	·0657	51	2·2	·0169	·43
9	·075	45	$\frac{5}{64}$	·0565	53	1·9	·0153	·39
10	·067	50	$\frac{1}{16}$	·0504	55	1·7	·0137	·35
11	·059	52	—	·0443	56	1·5	—	—
12	·051	54	—	·0378	62	1·3	—	—
13	·047	55	$\frac{3}{64}$	·0352	64	1·2	—	—
14	·039	60	—	·028	69	1·0	—	—
15	·035	64	$\frac{1}{32}$	·025	71	·89	—	—
16	·031	67	$\frac{1}{32}$	·022	74	·79	—	—

Diameter of standard head = 1·725 diameter of screw.
Length ,, ,, = ·75 ,, ,,
Slot ,, ,, = ·02 ,, ,,

SCREW THREADS FOR PIPING.

Nominal bore of tube.	Approximate outside diameter of black tube.	British standard pipe thread.		Number of threads per in.
		Diameter at top of thread.	Diameter at bottom of thread.	
In.	In.	In.	In.	
7	$7\frac{1}{2}$	7·450	7·322	10
8	$8\frac{1}{2}$	8·450	8·322	
9	$9\frac{1}{2}$	9·450	9·322	
10	$10\frac{1}{2}$	10·450	10·322	
11	$11\frac{1}{2}$	11·450	11·290	8
12	$12\frac{1}{2}$	12·450	12·290	
13	$13\frac{3}{4}$	13·680	13·520	
14	$14\frac{3}{4}$	14·680	14·520	
15	$15\frac{3}{4}$	16·680	15·520	
16	$16\frac{3}{4}$	17·680	16·520	
17	$17\frac{3}{4}$	17·680	17·520	
18	$18\frac{3}{4}$	18·680	18·520	

Nominal bore of tube.	Approximate outside diameter of black tube.	Whitworth thread.		Number of threads per in.
		Diameter at top of thread.	Diameter at bottom of thread.	
In.	In.	In.	In.	
1⅛	1½	1·492	1·3755	11
1⅜	1¾	1·745	1·6285	
1⅝	2 1/32	2·021	1·9045	
1⅞	2¼	2·245	2·1285	
2⅛	2½	2·467	2·3505	
2⅜	2 25/32	2·794	2·6775	
2⅝	3⅛	3·124	3·0075	
2⅞	3⅜	3·367	3·2505	

screwed portion and diameter. The heads are also of definite form and dimensions. As an illustration, there are ⅜ in. screws of variable lengths, as 1 in., 1½ in., 2 in., 2¼ in., 2½ in., etc. The heads may be square, hexagon, cup, cheese, mushroom, or countersunk, as desired. The length of a screw is measured regardless of the head. Bolts are only screwed for a portion of their length; generally they are forged and afterwards machined bright, both thread and stem, and finally the head. In the larger engineering establishments the screws and bolts are made on the premises, but in the smaller shops many screws are purchased from manufacturers. There are screwing or screw-making machines which are entirely automatic, and which produce screws or bolts directly from the bar stock, either round or hexagonal-headed, as is required. Where these screwing machines are not kept, owing to the smallness of the numbers required, the small bolts are forged and then turned up and screw-cut or chased, as the custom of the shop may be.

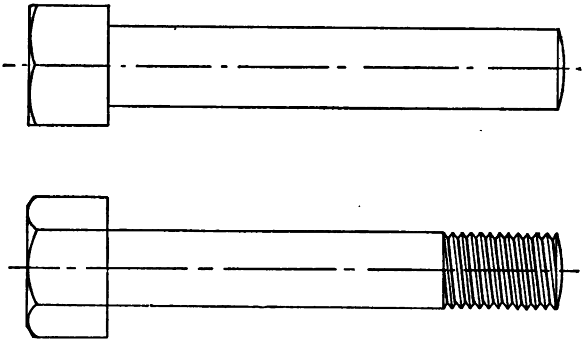


FIG. 136.—1" diameter "Whitworth" bolt.

A bolt is given in Fig. 136 to be turned as shown.

Now, there are two kinds of bolts, viz. first, "tight fitting," which means that the bolt has to pass evenly through two or more bored holes and hold the parts rigidly together, even before the nut is screwed on to retain it. Secondly, we have bolts not so precise in their fit, yet necessarily turned truly.

In every case, however, the screwed portion should be a good fit in their respective nuts.

The practice is to first turn and finish the bolt, and finally make the screw thread (see " Chasing ").

There are chasing lathes and turret lathes. These will be referred to later.

SCREW-CUTTING GAUGE

A screw-cutting gauge is given in Fig. 137. The Vee notch is used when making the Vee-nosed screw-cutting tools. A counter part is shown at the opposite end, which will gauge the shape and position of the thread after cutting. It will also indicate when the tool is properly fixed in the lathe tool rest. When other than screws of 55° angle are to be made, the part A, or B, can be swivelled to the correct angle, and retained by the milled screw nut C. The gauge is also used to indicate either the side rake or tool angle, and serves when fixing the tool relative to the surface of the work, as in external cutting, and similarly used in fixing internal screw-cutting tools. In the latter case, however, the gauge is held against the face plate, or tooled surface of the boss of the work, while the tool is adjusted to the gauge.

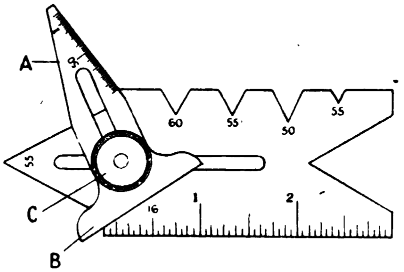


FIG. 137.—Screw-cutting gauge.

Definition of Whitworth Thread.—In the Whitworth form of thread

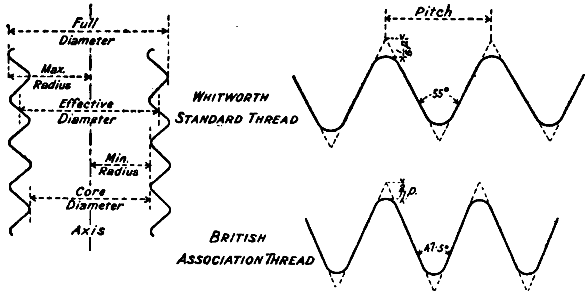


FIG. 138.

the angle between the slopes, measured in the axial plane, is 55°; the threads are rounded equally at crests and roots to a radius of 0·14 times the pitch, and, therefore, the depth of the thread is 0·64 times the pitch.

For simplicity, the depths in the table given have been approximated to the fourth decimal place (*i.e.* correct to within 0·00005 in.), and the values given are to be taken as defining the standards.

In the British Association form of thread, the angle between the slopes, measured in the axial plane, is 47·5°; the threads are rounded equally at crests and roots to a radius of nearly two-elevenths of the pitch.

In Fig. 138 is given an explanation of the headings of the table of Whitworth thread constants given, and also a drawing of the outstanding features of the two types of thread described above.

Cutting Deep Vee-threaded Screws

Deep Vee-threaded screws require careful treatment, or the screw cutting tool will be unduly punished, and the threads torn beyond remedy.

Generally the material to be cut is mild steel, and it is not always homogeneous. All the slides should be overhauled and made tight especially should a tension be put on the setting-up screws of the tool rest. After a few traverses have been taken the cutting tool should be made to cut on the sides until a flat surface appears at the root, the deepening must now be done by right- and left-hand cutting, starting by a shallow groove in the centre. Working the tools by "tacking," first to the right and then to the left, enables the workman to do more work in a given time.

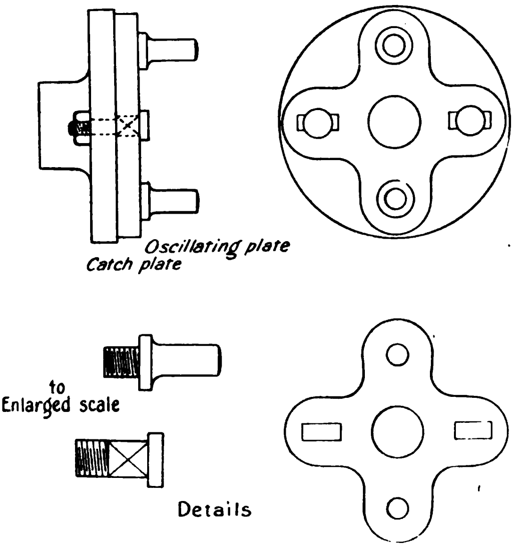


FIG. 139.—Clements double driver.

The single Vee point is substituted by a right- and left-hand side tool when coarse pitches have to be cut, but an opening is previously made for these by a square-nosed parting tool, which is ground to the proper clearance on its sides. The square-nose tool should be about $\frac{1}{16}$ in. narrower than the actual width of the screw at the root of the thread. This will leave $\frac{1}{32}$ in. on each side for finishing. The driving gear is always an important factor, and should be tested before cutting commences, otherwise if the tool digs, or is in any way fouled, the tendency is that either the clips will skid, the tool nose break off, the gears fracture, or something worse happen. It is usual for screw-cutting lathes to be fitted with double drivers, so that the carrier will receive an equal pressure on each side. (See "Clements" driver, Fig. 139.)

GAS-PIPE THREADS AND HAND SCREWING

Piping is too thin to be cut to the ordinary standard screw sizes, therefore it has a special standard, the threads being of a finer pitch. This being so, the threads must be fully cut to proper depth by having the outer diameter made to correct dimensions. To ensure the pipes "starting," a slight taper is given to the leading threads. This must not be allowed for more than two or three threads, otherwise a portion of the pipe will be useless; a further reason is that the pipe screw is of a limited length, and cannot be secured properly on a tapered screw.

Pipe-thread dies are of two kinds—solid, and split. The solid die cuts the screw at one cut, but in these there is no real means of clearance to the cutting edges. The tops may be backed off, to assist the cutting edges, but the roots cannot be touched. The screw thread in the die must be standard diameter, therefore it has to be cut with a master tap of standard diameter, hence there must be a rubbing action. This is exemplified in the "Lancashire plate," which has no clearance. In split-dies the master tap used is of a larger diameter than standard size, so that when closed on the work, the dies show a clearance. There is also the Whitworth three-part dies, and the Wiley and Russell adjustable dies. Now, comparing lathe cutting tools, they have a leading and a following side; that is, the cutting edge penetrates the metal according to the inclination of its leading cutting angle. This principle also applies to dies, therefore they cannot cut in both directions. Where this is attempted the dies have some of their cutting edges destroyed even when part of the set are placed in a reversed position. Obviously by this arrangement there are some edges always rubbing, since they move in an opposite direction to the cut. This fact appears to receive little attention, perhaps it is owing to the modern practice of making all screw threads as far as practicable by machine, in which case the cutting dies are adjusted most carefully, until the screws produced are correct in diameter and shape. There is a very decided lead given to the dies, therefore to reverse them on the work would be disastrous, if a great amount of cut were attempted.

NOTES ON SCREW CUTTING AND CHASING SCREWS BY HAND TOOLS

Most screw threads which are of a fine pitch, and those of standard size, when for important work on spindles and shafts, are cut in the lathe. It is the practice to complete the turning as far as possible before attempting to make screw threads. After this is done the change wheels are calculated and fixed in their respective position. The screw-cutting tool is then adjusted and fixed, and the screw is cut almost to the full depth. We will assume that a 1-in. bolt is to be turned and screw cut to fit a standard nut (Fig. 136). The guide screw of the lathe being $\frac{1}{4}$ in. pitch, or twice as coarse as the pitch of the screw to be cut, *i.e.* $\frac{1}{8}$ in. pitch, or eight threads per inch. Now, the gears must be in the same ratio, or one wheel must have twice the number of teeth of the other. Now, if we refer to the rule we shall see that the guide screw is represented by the number of its threads per inch, and the screw to be cut by its number of threads per inch, thus we have $\frac{\text{guide screw}}{\text{screw to be cut}} = \frac{4}{8} \times \frac{10}{10} = \frac{40}{80}$, which represents the wheels required (Fig. 140A).

The top wheels are always the drivers, and the lower wheels the followers, therefore a 40 change wheel is placed on the lathe spindle end, and the 80 fixed on the guide screw. To cause motion between these, a central or intermediate wheel is fixed. This connecting wheel is not in the calculation, and may be of any number of teeth to mesh with the spindle wheel, and that on the guide screw. It also serves to direct the rotation of the guide screw, making it revolve in the direction of the spindle. After cutting, the hand rest is fixed and the screw finished by chasing. The tool is fitted in a long handle and made to slide on the rest evenly, while the cutting edges round off the top and bottom of the threads at the same time. To keep the work quite parallel is difficult, as the tool is generally forced into the screw more at the centre than at the ends. For this reason calipers provided with a broad nose are used to repeatedly gauge the diameter. The correct position at which to hold the chaser is important. If held too high the tops of the threads will be cut away.

Notes on Screw Cutting and Lathe Movements

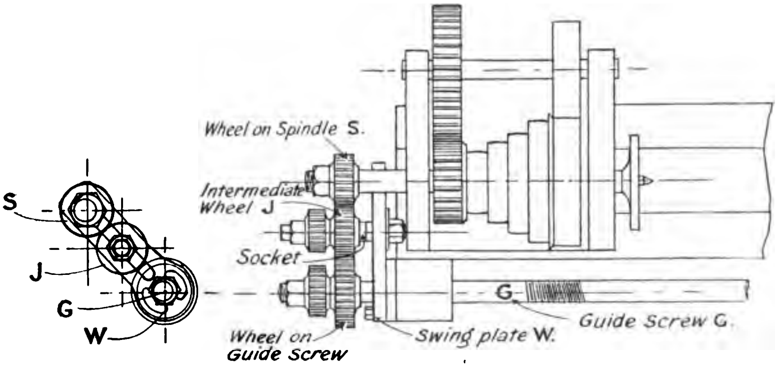


FIG. 140.—General arrangement of gears for screw cutting.

In screw cutting, the movement of the carriage and tool is much quicker than for ordinary turning, consequently the operator must be more alert. To screw-cut successfully, one must be perfectly familiar with the motions of the various parts of a lathe, and be able to make any essential adjustment. He will be able to do accurate turning and boring to gauges, should have a good knowledge of cutting, and why cutting tools vary in shape and hardness. He must also understand when to advance the speed, and when it should be reduced; what material cuts better if lubricated, and which needs none. He should know if the angle of the tool is correctly formed, and be able to "set" the cutting edge relative to the surface and axial alignment of the work in hand.

There is also the calculation of the change wheels, and the selection of the wheels to produce the required pitch. For illustration of this two examples may be taken. Example 2, Fig. 140B. In a lathe having a guide screw of $\frac{1}{4}$ in. pitch, a screw is required on a $\frac{3}{4}$-in. bolt. Now, according to the first rule we have: Place the number of threads

Examples of change wheels for screw cutting.

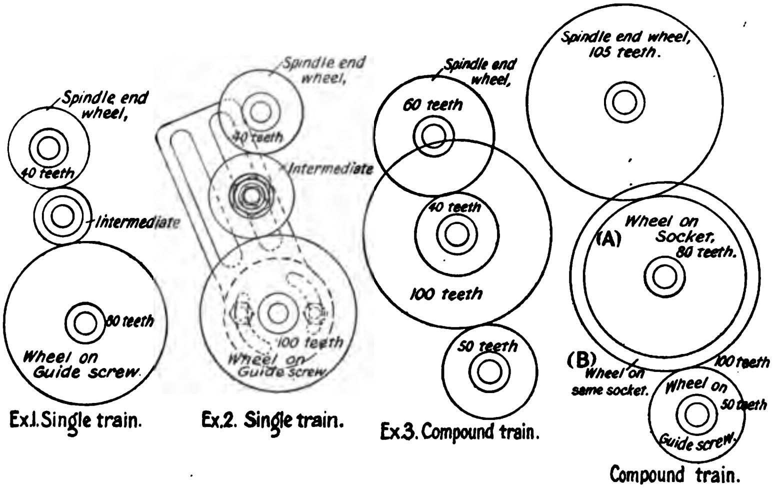


FIG. 140A. FIG. 140B. FIG. 140C. FIG. 140D.

of the guide screw for a numerator, and the number of threads of the screw to be cut for a denominator; thus: $\frac{\text{guide screw}}{\text{screw to be cut}} = \frac{4}{10} \times \frac{10}{10} = \frac{40}{100}$. Now, the upper wheels are always drivers, therefore according to diagram Fig. 140B, we place a 40 wheel on the spindle end, and a 100 wheel on the guide screw; any wheel serves to connect the two gears.

Example 3, Fig. 140C. In a lathe having a guide screw of $\frac{1}{2}$ in. pitch, a screw is to be cut $1\frac{1}{2}$ in. pitch. Rule 2: When the screw to be cut has not a complete number of threads per inch, find a number of inches containing a complete number of threads to be cut, and of the guide screw. Thus we have $\frac{3}{2} = 2$ threads in 3 in. to be cut.

In the same distance, 3 in., we have 6 threads, Fig. 140C, therefore according to Rule 1 we have $\frac{6}{2} \times \frac{10}{10} = \frac{60}{20}$, *i.e.* 60 wheel on the spindle and 20 on the guide screw. It is, however, the wiser plan not to have so small a wheel as 20 on the guide screw, when cutting coarse pitches, especially in a single train, as the present case shows. The reason for this is that all the change wheels are subjected to a severe strain in cutting coarse threads, but the 20 is least able to bear the load, owing to the keyway seat, and the roots of the teeth being closely situated. This being so, a compound train is preferable.

It is the present practice to cut all gears in lathe construction and machine tools. There are, however, many lathes working with cast gearing, including the change wheels.

With reference to the third example we have

$$\frac{6}{2} \times \frac{10}{10} = \frac{60}{20} \times \frac{50}{50}$$

Now we may double the 20 = 40 and double the 50 = 100, therefore we have

$$\frac{60}{40} \times \frac{100}{50} = \frac{60}{40} \times \frac{100}{50}$$

The upper wheels being drivers are placed as in diagram Fig. 140C, 60, 100, and the followers are also as shown 40, 50.

Examples occur of odd pitches as $1\frac{5}{16}$ in. pitch, Fig. 140D; bringing this to its lowest term, we have $\frac{21}{16}$ pitch = 16 threads in 21 in., but in 21 in. of the $\frac{1}{2}$ in. pitch guide screw we have 42 threads.

Therefore the ratio is $\frac{42}{16}$ This multiplied by $\frac{5}{5} = \frac{210}{80} \times \frac{100}{100} = \frac{105}{80} \times \frac{100}{50} = \frac{105}{80} \frac{100}{50}$. (Fig. 140D.)

Note the 105 is fixed on the spindle end gearing with 80 on the socket, also 100 on the socket gearing with 50 on the guide screw.

That is a driver 105 engages with a follower 80, and a driver 100 engages with 50.

The drivers may be reversed in order, if found to gear more satisfactorily.

CUTTING SQUARE-THREADED SCREWS

Square-threaded screws are used very largely in machine tool construction and other mechanism to transmit motion to the various slides. It is therefore important that all such screws be carefully and accurately cut. There are several important points to be observed. In the first place, the guide or leading screw should be of a reliable pitch from end to end, and a good fit both in its nut and its bearing, also truly controlled by well-fitting lock nuts.

The change wheels, and indeed all gears, should be machine cut. In this way the teeth can be meshed so as to admit no back lash, which is most desirable especially in screw cutting. In traversing the lathe saddle the Vee strips should perceptibly grip the bed while the transverse slide and the slide rest should fit well in their respective slideways.

The lathe spindle also must receive special attention, being a well-adjusted fit in its bearings, especially in the front one. Example: A shaft to be screw cut we will assume is already turned and finished, as shown in Fig. 236 which represents the slide rest screw, viz. of 6 threads per inch left hand.

There are three distinct methods of cutting these screws: (1) is to take out with a narrow parting tool a portion down to the bottom of the threads' diameter; this is just to allow the screw-cutting tool to enter at the proper starting place each time a fresh cut is taken. Cutting out this concentric groove somewhat weakens the screw, and for that reason is not always adopted. (2) The tool is first started on its journey and the cut gradually put on until the full depth has been reached. The (3) method is to drill a hole and cut a taper slot in the near side for the tool to enter freely. Whichever plan is adopted the shaft will be too slender to be cut without a stay. A finger stay, as shown, is often used, but a much better because more reliable form is to have a bushing with a saw slit from the outer to the inner diameter. The bushing is fitted to slide on the shaft and is housed in the travelling stay. Adjustment is given as required by tightening the front plate, the arrangement used in this manner ensures the screw to be firmly held up to its cut during the process of tooling, and since deeper cuts can be taken more screws can be produced in a given time.

To be certain that the tool starts precisely at the same point each time, a stop is secured to the bed for the saddle to butt up to. Now, since the relation of the screw to be cut is not complete, *i.e.* the guide screw being 4 per inch and the screw to be cut 6 per inch, there must be marks made to indicate the correct position of the lathe spindle and its work relative to that of the guide screw; when this is done the nut-box lever can be lowered and the nut made to engage with the screw correctly.

To do this properly requires care, and it is wise first to pull the belt by hand until the guide-screw threads are quite opposite those of the nut; this, however, cannot be seen, but is felt for, by giving a slight pressure to the nut-box lever, the latter being very gently lowered until there is complete coincidence between the nut and guide screw. The chalk marks are then made. The best place for this is usually on the front gear wheel where its teeth pass the headstock for the one part, and on the guide screw just as it leaves its bearing for the other part.

A cut can now be put on, and the lathe started. Oil will have been used on the flats and Vees of the lathe bed, while the tool will be lubricated with soap and water, "Radol," or other mixture. In most modern lathes there are divisions on the saddle screw (a dial), which will rotate on its axis. A zero mark is cut on the front bearing and it therefore follows that the screw may be turned to any desired amount and arrested by noting its position relative to the zero mark on the saddle-screw bearing; thus it may be withdrawn, and again returned to its original position, but if this were all there would be no cutting taking place whatsoever. Therefore by turning the screw just one mark over the zero a cut is easily put on, and then, while the tool is operating the index marker can be returned back one degree. This method is very useful as a general principle for all machine tools, if the pitch of the feed screw is known, then the actual depth of cut can be measured and in the case of screw cutting the depth of cutting can be gauged without actually measuring the diameter at the bottom of the thread.

Again, in milling it is proved to be a most useful appliance. By its means the precise depth of cut may be predetermined, and the dial fastened at that setting for all pieces of work of a similar character. The first cutting tool for the best screws is made about $\frac{1}{64}$ in. too narrow; this tool is first passed down to almost the full depth, and then removed for the insertion of a second or finishing tool of the correct width. By thus removing only a small fraction, viz. $\frac{1}{128}$ in. on each side the threads are finished quite smooth and bright, with this advantage the life of the finishing tool is considerably lengthened, since it has so little strain on its cutting edge, while the product is of the highest class.

Now, in all machining there is more or less heating of the work, and it is obvious that in screw cutting in particular the heating and consequent expansion of the work should be kept at a minimum. This, of course, is dependent upon two factors, the first is a plentiful supply of lubricating fluid, and secondly, to leave as little work as possible for the finishing tool to do.

The dies of the travelling stay should be made of hard wood, and after fixing are preferably bored in their place on the lathe saddle transverse slide ways. A bar and cutter can be used and the hole bored $\frac{1}{8}$ in. over size of the shaft, a steel liner of $\frac{1}{16}$ in. thick can be bent to fit the dies and retained by means of wood screws.

When quantities of similar screws are to be cut a metal stay of the cap and block type is preferable. A shaft of the same diameter as the screw to be cut will serve to try through the dies, which should be properly adapted, and then returned to their place in the travelling stay. The dies are pressed to the shaft by means of a steel plate and setting-up screws; the proper tension can be better judged by starting the lathe and running the saddle up and down the bed. When the dies are proper, the loose-head poppet can be released and the centre drawn back; there should be no perceptible movement at the end of the shaft when the centre is again adjusted in position. The screw to be cut being left-handed, the tool will be fixed on the right side of the stay, thus enabling the workman to put on the cut at a definite spot, also allowing the tool to traverse without hindrance up to the end of the screw, viz. to the loose-head poppet centre. In returning the saddle for a fresh start the dies can be brought close up to the shoulder or collar on the screw, thus ensuring the clasp nut dropping correctly in gear on the guide screw, each time that the marks on the guide screw and those on the spindle wheel agree.

When cutting screws which are left hand, and not a multiple of the guide screw, a stop can be secured on the lathe bed, against which the saddle can be brought back, after each cut has been removed.

It should be noted that it is important to wind the saddle to the stop with a gentle pressure so that there will be no risk of the actual position of the screw-cutting tool being disturbed. This also applies when the lathe is cutting right-hand screws, and the saddle is returned to the loose head or some other stop. It is also very necessary to lower the clasp nut very steadily into its place on the guide screw. Any hurried movement or forcing will change the position, and if the cutting tool is made to operate the threads will either be cut irregularly or the tool nose will be broken off. There is a slight movement of working parts, even when most carefully adjusted; this can be seen when screw cutting threads of a very fine pitch.

MULTIPLE THREADED SCREWS

Coarse pitches are usually only employed on screws of large diameter and screw gearing as in reducing gear by worm and wheel. In the latter case the screws may be of a comparatively small diameter, but having several starting places. These starting places are called "leads," that is, a screw is known to be a double-threaded screw, when it has two starting places or leads. Now, the "pitch" of a screw is constant, however many leads such a screw may have; for instance, a screw may be cut on a shaft of 2-in. diameter, $\frac{3}{4}$-in. pitch, with one lead, or, as it is called, a single-threaded screw, the nut for which will travel equal to one pitch, or $\frac{3}{4}$ in. for 1 revolution, another shaft of a similar diameter may also be cut $\frac{3}{4}$-in. pitch, with two leads, or, as it is called, a "double"-threaded screw, the nut for which will travel equal to one pitch for one revolution as in the first example. There is, however, a great advantage in having a screw cut with two, three, four, or more leads (see Fig. 141). An instance of this is common in the saddle screw for a lathe, which is in this case $1\frac{1}{8}$ in. diameter, $\frac{1}{2}$ in. pitch, with

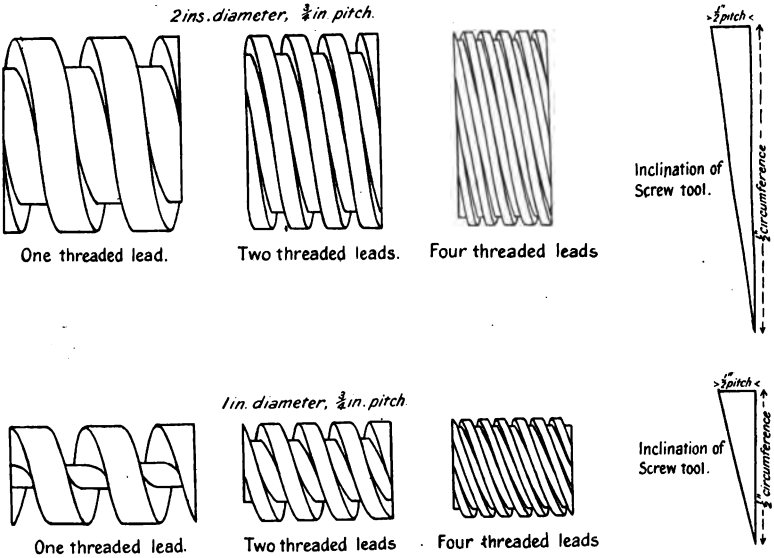


FIG. 141.—Screw-cutting multiple screw threads.

two leads. Now, since the pitch is coarse and the diameter small, there will, to all appearance, be half of the pitch having one thread and one space, and the other half of the pitch containing another thread and space, in all two threads and two spaces. This, however, is not correct, there will really be one space cut out with a narrow tool, leaving a thread three times as wide as itself; this is then cut through the centre with the same tool, to form a second space, leaving a thread on either side, but when finished only showing two threads and two spaces, actually resembling in appearance in this respect a screw of $\frac{5}{16}$ in. pitch only, which is made with a cutting tool $\frac{5}{32}$ in. wide.

Now, again, the depth of a screw is equal to the width of the thread, or equal to the space, so that it will be obvious that the more leads a screw has for a given pitch the narrower must be the tool, and consequently the shallower will be the depth of the screw when it is cut. Assuming that it is imperative for a lathe saddle screw to be cut $\frac{1}{2}$ in. pitch, and we were to cut it with one starting place only, the cutting tool being $\frac{1}{4}$ in. wide and entering the screw $\frac{1}{4}$ in. deep, the diameter at the roots of the threads would be only $\frac{5}{8}$ in. Moreover the saddle screw has to be bored to receive a rod not less than $\frac{1}{2}$ in. diameter; it therefore follows that the diameter of the screw would have to be increased, or a screw cut having two leads and, thereby, an increased diameter at the roots of the threads would be needed.

It is the rule to consider the width of a tool for one lead, and divide by the number of leads required. Thus, a screw 1-in. pitch is cut with a tool $\frac{1}{2}$ in. wide, and a screw 1-in. pitch with two leads will need a tool $\frac{1}{2} \div 2 = \frac{1}{4}$ in. wide. Therefore, a screw 1-in. pitch, with four leads is cut with a tool $\frac{1}{2} \div 4 = \frac{1}{8}$ in. and so on, however many leads there may be. (See Fig. 141.)

It is important to note that all screws of a given diameter and pitch are of the same angle, however many leads or starting places are decided upon. This being so, a sheet steel gauge can be filed up and stamped for screws of a given diameter and pitch. To make such a gauge draw a horizontal line, H, and erect a perpendicular P; using C as a centre, mark off on H, a distance J = to the pitch. Next on P mark off a distance Q = to the circumference of the screw to be cut, then by joining J, Q we have the angle required, to which angle the screw-cutting tool's leading side is to be filed up. Looking at the sketch, Fig. 142, it will be evident that coarse pitched screws of small diameter will necessarily have a much greater slope than threads of an equal pitch cut on shafts of a large diameter.

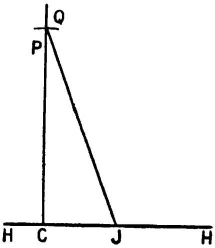


FIG. 142.—Angle of screw-cutting tool.

There are several methods of arrangement for cutting multiple threaded screws. Undoubtedly, the simplest one is to cut a multiple of the guide screw, such as $\frac{1}{2}$-in. pitch two leads with a guide screw of $\frac{1}{4}$-in. pitch, or 1-in. pitch two leads with a guide screw of $\frac{1}{2}$-in. pitch. Here we have a start on the screw to be cut at each revolution of the guide screw, so that by chalking two places diametrically opposite, on the lathe face plate, the clasp nut will engage with the guide screw at either mark. In this case the screw-cutting tool may operate on both threads cutting alternately without ever stopping the lathe. There are many other pitches which can be cut, by stopping the lathe after each run up and pulling the belt by hand until the desired number of revolutions of the work agrees with the guide-screw markings and then commencing on each thread in turn as above shown.

When it is not convenient to cut the screw as above stated, the wheel on the spindle end must be divisible by the number of leads the screw to be cut must have. There are two methods of disconnecting the train of gears. First the spindle end wheel is counted and divided by 2 if for a screw having two starts are to be given, the precise half being denoted by making a chalk mark below the space, calling the tooth in gear, I, and the second mark II, which of course will be diametrically opposite the mark I. The belt should be pulled round for one complete revolution, and then the socket can be withdrawn, bringing with it the intermediate connecting change wheels. The disconnection being thus made, the lathe spindle can now be rotated half a revolution, just until mark No. II is precisely right to occupy the position previously occupied by No. I.

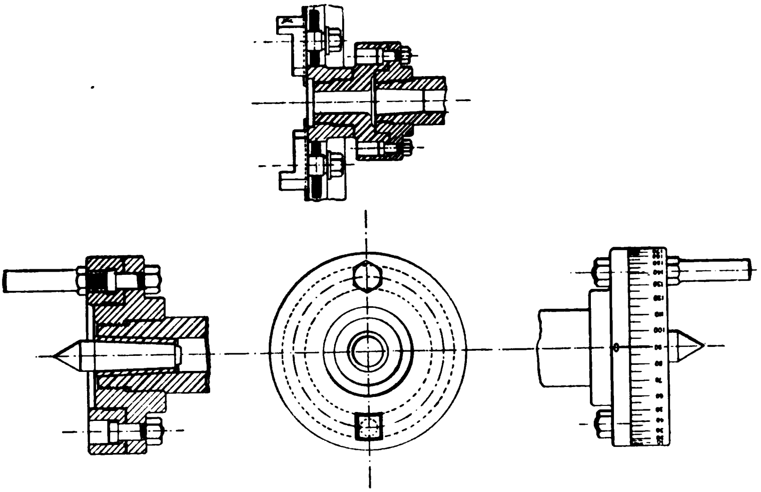


FIG. 143.—Multiple thread-cutting plate.

When great quantities of similar screws are to be made a special form of driving plate can be made having the driving studs precisely spaced, equal to the number of leads the screws are to have. (See Fig. 143, Multiple thread-cutting plate.)

SOME POINTS IN A GOOD LATHE

Cutting tools used in a machine can only be made to properly perform to their best advantage when the steel is of the right quality, the cutting edge keen and ground to the most suitable angle, and the machine carefully designed, constructed, and used intelligently.

The correct proportioning of a machine tool is most interesting, obviously necessitating a knowledge of the possibilities and of the endurance of the cutting tools employed. Perhaps there is no machine tool which has received more attention than the lathe in one form or another. Although the first of all machines, yet still the king, and seems quite likely to hold its foremost position, great advances towards its perfection have been made in recent years. Considerable amounts of metal have been added to make it rigid under the increased duties put upon it, by the increase of feed and speed, when working with air-hardened steel. The following points are amongst those which have received attention, and therefore can be looked for in a modern 8-in. centre lathe :—

(1) Driving spindle, large, hollow, hardened and ground throughout, having bulky and long necks fitting in journal bearings, with ball bearings to receive the thrust.

(2) Gearing all machine cut, including change wheels for screw cutting, the latter preferably in a nest.

(3) Bearings phosphor bronze adjustable, long, compact, and dust-proof.

(4) Shears, broad, tied at frequent intervals.

(5) Bed, to floor line under head, deep box form, springless, gapless.

(6) Fast head, long, bulky, all gear-driven, dust-proof.

(7) Speed variable, pulley drive, handle feed.

(8) Transverse slide, broad, long, adjustable gib strips.

(9) Compound rest, short, broad, no overhang.

(10) Catch plate, having double drivers. Face plate (16 in.) broad top, webbed back, few slots, metal 1¼ in. thick, loose headstock, massive body, set over slide, poppet and screw combined. Headstock sliding on its own portion of the shears.

LATHE CENTRES

Lathe centres form a subject for special comment. Too much care cannot be given to their correct up-keep.

In a new lathe there should be a full set of centres all of which precisely fit in the taper holes, provided in the fast-head and loose-head spindles. To obtain this perfection of interchangeable fitting, the holes and the centres too have been carefully ground, and lapped. The centre points are also turned and ground to one uniform angle. The one most approved is 60°, but in some medium and heavy lathes the centres are 90°. It will be easily understood, if true turning has been done in the lathe under the above conditions, any interference will at once cause error. Now, there are a number of ways in which error may creep in and cause the work to be turned eccentrically instead of true, or to be made taper instead of straight. Small specks of grit in the fast headstock spindle bearings or on the tapered part of the centre, or either on the centre point or in the centre hole in the work, will make the work between the centres eccentric.

Any bruises on the above parts also give similar results. The loose-head centre may be faulty, any rough marks on the tapered portion will be sufficient to throw the centres out of alignment, and if work is turned under these conditions, it will be taper instead of parallel when finished. The centres should therefore be kept away from other tools, and the holes in the spindles plugged with clean waste, if boring has to be done at the lathe. To ensure the fast-head centre point being true, a mark is made on the body to correspond with a similar mark across the mouth of the spindle, so that every time the centre is inserted the marks agree. Some turners used to leave the fast-head centre point permanently soft, and re-turn it up as it became necessary. This, however, has not been much practised since centre grinders can do the work much better, quicker, and to the correct angle.

Sliding and Surfacing. Feed, Speed, etc.

"Sliding in the lathe" means the traversing of the saddle carrying the cutting tool along the bed, as is the case in turning a shaft.

"Surfacing in the lathe" is the traversing of the transverse slide and rest carrying the cutting tool across the saddle towards or away from the centre, as in turning a disc on the face or a facing cut across a face plate.

Usually for small lathes the mechanism is actuated by friction cones; in the larger lathes, the gear is direct by sliding key or by means of a clutch attached to one of the gears. The rate of feed is the distance traversed, usually reckoned in inches; thus a lathe may be said to be traversing at 8 per inch, *i.e.* for every revolution of the work the tool will have moved $\frac{1}{8}$ in. of travel. The rate of feed varies considerably for different work and diameters, and may be from 50 down to 4 per inch. Speed is the peripheral speed of the work in feet per minute multiplied by the rate of feed.

Let r = radius of work in feet.
V = the speed of cut in feet per minute.
R = revolutions per minute to produce V.

then $$2\pi r R = V, \quad \text{and } R = \frac{V}{2\pi r}$$

It is now impossible to give a rate of feed and speed commonly used in practice, owing to the development of tool steel, since some of the tools in general use have a capacity to hold up to the work at speeds more than double the rate possible with carbon steel. Further, there are so many varieties of work, under the term "Engineering workshop practice," that what would be quite suitable for one class would be too fast or too slow for others. We cannot quite differentiate between Marine Engine, Loco Engine, Machine Tool, and Textile Machine construction. In the former the dimensions of the parts are in feet, in the latter in inches and parts of an inch. There are two other factors—the amount of metal to be removed, and the condition or capacity of the machine to remove it.

SETTING AND TOOLING WORK IN THE LATHE. CHUCK AND FACE-PLATE WORK

A considerable portion of the work to be bored and turned in the lathe is usually held in an independent jaw chuck, but if of an irregular outline it is clamped to the face plate with parallel strips to allow the boring tools to clear the work easily. Circular, octagonal or square castings can be chucked. The ordinary method is to measure the object and set the jaws approximately before the work is secured. Generally, for the guidance and facility of setting work, rings, *i.e.* very shallow grooves are made on the surface of the chucks and face plates, so that before rotating the lathe the distance from one of the rings to the top of a jaw should be taken, and the remaining jaws similarly adjusted.

The lathe may now be revolved at a high speed, and with his arm supported on the rest the operator may hold a piece of chalk close to the work, and a mark will indicate the highest point. On stopping the lathe, the mark being brought to the bottom, the opposite jaw should be eased and the one nearest the mark tightened, the process being repeated until the chalk marks are uniformly distributed.

Circular work of a superior finish and contour, *i.e.* castings made from turned iron patterns, may be secured in a self-centring chuck, also bar steel stock which is now rolled to $\frac{1}{1000}$ in. of error. In such cases setting is not considered. This is exemplified in automatic turret lathes and stud and screw machines, where the stock is instantly gripped in a collet or self-centring grip chuck, with no alteration necessary, but just side movement.

FACE-PLATE WORK

Discs, face and chuck plates, thick annular rings, and many kinds of wheels may be gripped very forcibly in a four-dog chuck (Fig. 144). The dogs are entirely independent of the plate and are, therefore, adaptable to any lathe of similar proportions; they will fit either in a rectangular slot or a square slot hole. By the aid of a set of dogs, securely placed, heavy pieces of work may be bored and faced and partly topped at one setting. After this the work is reversed for tooling the other side.

SETTING AND TOOLING DOG CHUCK WORK

When the diameter of the bore is a large one the inner face (next the face plate) may sometimes be tooled for a considerable distance before the casting is reversed.

This applies chiefly to annular rings and plates which have to be tooled on both sides. In such cases a quick re-setting may be effected by clamping the work directly to the face plate and gauging its position by means of the grooves on the plate, the final setting being accomplished by means of a boring tool made to touch the bore, the work being adjusted until the tool may be inserted and made to touch at any point within the circumference.

To do this the saddle must be wound to the work and away as the clamps and bolts come round. An alternate method is to grip the ring by its bore in a self-centring chuck or, failing this, an independent chuck may be employed where the diameter can be admitted. Forgings and castings too of a slender section cannot be secured in a jaw chuck, but may be held by frictional contact to the face plate. It is obvious that ordinary clips and bolts would alter the shape of the ring if sufficient force were exerted necessary to drive it. The customary method for such work is to fit bolts with collars near to the periphery, and then insert wedges to hold the ring. After the ring is finally set there are clips screwed hard to the plate at uniform distances apart, the ends of the clips just touching the work. There is, of course, a tendency for the work to skid, but with sharp tools, shallow cuts, and fine feeds, the surface may be tooled over, and if the metal cuts sweetly the hole may

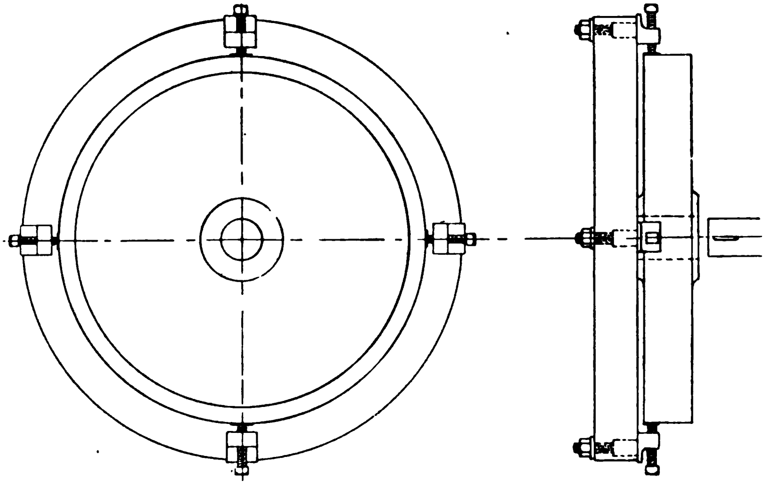


FIG. 144.—Four-dog chuck holding plate wheel.

also be bored. The plate can now be stripped of the tackle and work, and the latter may then be secured by the outer rim with two clips until the bore is truly set. (See Fig. 145.)

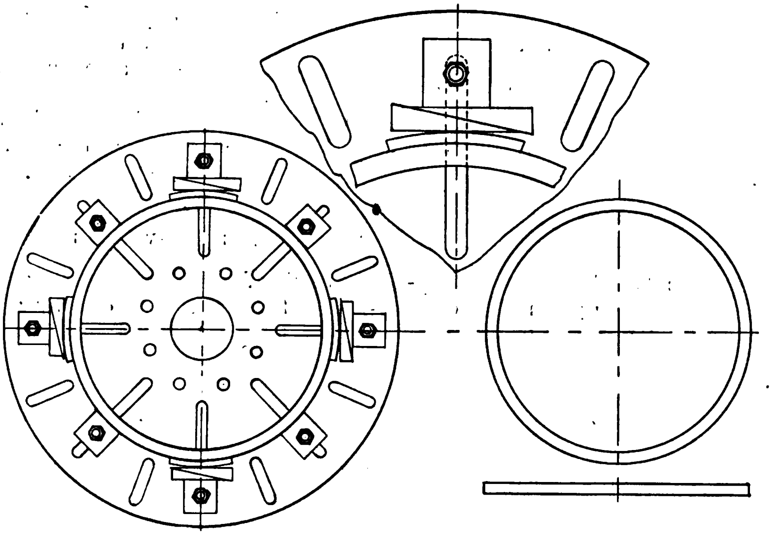


FIG. 145.—Holding slender annular rings.

RE-SETTING LATHE WORK

When plates and discs, and similar work having a flat surface have been tooled and finished on one side, it is customary to first note that the plate runs perfectly true before the work is re-set for tooling the opposite face.

When there is no need for parallel strips, whether the object to be turned is of heavy or light construction, it is a good practice to place a sheet of paper on the face plate before the turned surface is secured; this gives the work a better bite, and, therefore, increases the resistance to the action of the cutting tool. Care should also be given to the form of the tool's cutting edge, the more decided and short the attacking surface of the tool, the less will be the friction set up. Suppose a tool has to take a cut $\frac{1}{8}$ in. deep, better results will be obtained if the edge is in actual contact $\frac{3}{16}$ in. than a similar tool having a contact of $\frac{3}{8}$ in. or more. This is exemplified in the cutting tools used in the Hartness turret lathe, adopted after considerable experience in the behaviour of cutting tools.

This principle partly obtains in the Vee form of roughing-out tool for heavy turning, but is often lost sight of in the smaller shops, where each operative generally has the opportunity of grinding the tools to his own liking. A further example: in railway loco wheel tyres the returning is a difficult task, and considering the coarse traverse used, and the fairly smooth surface obtained, pointed tools would not be a success, nevertheless, the underlying principle of all good cutting is to *get the tool nose well under the hard outer surface and keep it there* if at all possible. Therefore, a definite tool angle and a full depth of cut will give better results if the rate of feed is reduced than a broad-nosed tool having less penetrating power taking a shallow cut at a quicker feed. (See "Forms of Cutting Tools," Fig. 127.) Again, in surfacing cast iron of an irregular form, once a keen tool gets well into the metal both speed and feed may be sacrificed before depth of cut, since the scale of cast iron will take the edge of the hardest high-speed cutting tool.

FIXING, TURNING, BORING AND BOSSING FLY-WHEELS

The method of holding a fly-wheel to the face plate of a lathe is shown in Fig. 146A, B, and C. Fly-wheels for gas and oil engines are essentially heavy, and, therefore, great care has to be given to obtain a substantial grip of the arms, so that there will be no vibration or movement when the various cutting tools are under operation, nor of springing by the pressure of the clips.

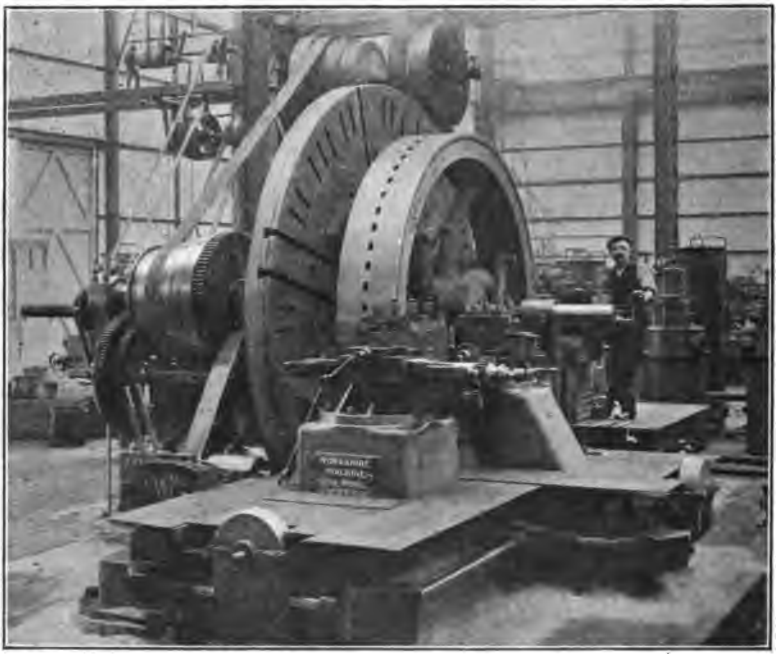


FIG. 146A.—Boring and turning heavy fly-wheel.

A brief description of some cardinal points of the above lathe will serve to show that in the design consideration has been well given to the facility of operation and to the duplex cutting.

The base plate which extends under the whole of the machine is of a strong box section, ribbed and barred, and on the upper surface carries three pillar-type rests, one being used for turning across the rim, another to simultaneously turn down both sides of the fly-wheel, while the third operates upon the boss and carries the bar support. Continuous feed motion is fitted to each rest, which is driven from a gear box giving three changes by levers; this motion is imparted through powerful worm gearing to shafts inside the rests, and finally to the screw which actuates the tool slides. Referring to Fig. 146A, B, and C, the headstock is bolted directly to the base plate and carries a large driving spindle, viz. 16 in. diameter by 24 in. long in the front neck. This is a noteworthy feature, and shows the strength of the spindle to be well beyond the power of vibration even when high-speed steel tools are used and fed at rapid rates. The large speed cone carries a 6-in. belt, and may be geared to the face plate through three different ratios of gearing, thus giving a range of 12 speeds with a single speed counter

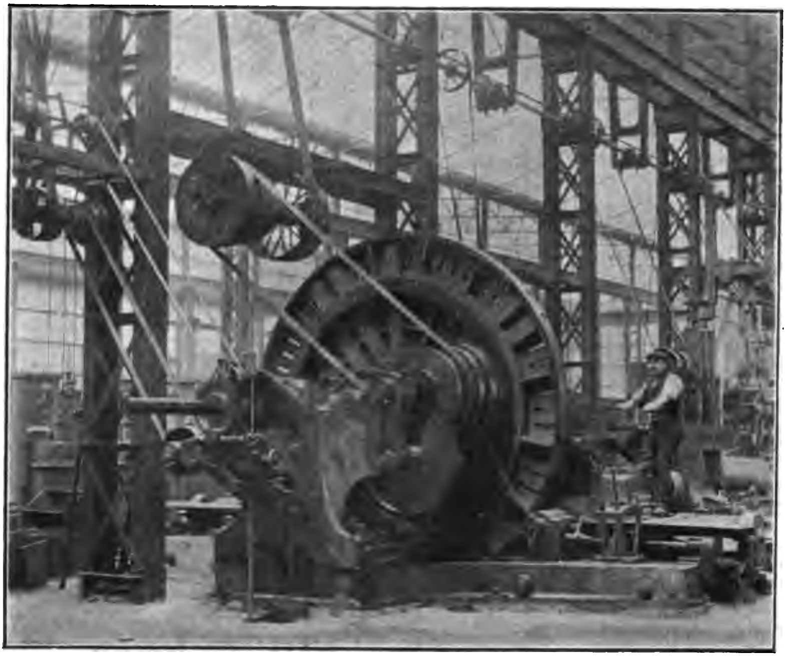


FIG. 146B.—Heavy fly-wheel lathe.

shaft, the total gear purchase being 154·6 to 1, and a belt speed of not less than 1500 per minute. The face plate is carried on a large collar solid with the spindle, and is 11 ft. 6 in. diameter, it is also supported underneath by rollers engaging with the rim.

The boring headstock is fixed to the back of the main headstock, and is entirely independent both as regards feed and drive from the other parts of the machine. A change feed gear box giving four changes feeds the boring bar by means of a worm wheel threaded on to the bar itself, thus giving the most powerful feed. The bar may be quickly operated from the front of the machine, thus enabling the workman to see the exact position of his work.

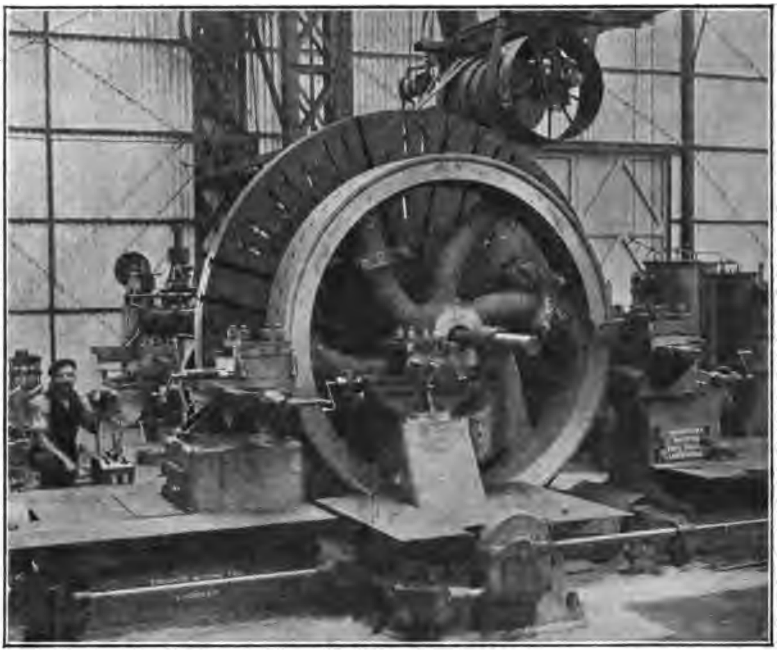


FIG. 146C.—Heavy fly-wheel lathe.

TURNING FLY-WHEELS

Heavy fly-wheels are tooled at a very quick rate. In the most recent practice a comb form of cutting tool is dug straight into the face of the wheel; this has the effect of breaking up the metal in a somewhat similar manner to the roughing cutter with serrated teeth used on the heavy type milling machines.

On the opposite side of the fly-wheel a broad-nosed tool of the full width is made to operate over the whole face, and a third tool is engaged in boring at the same time. A fly-wheel of 4 ft. diameter by 6 in. face and $2\frac{1}{2}$ in. bore was finished complete in thirty minutes.

It will be obvious that to stand so severe a strain it will be necessary for the slides and moving parts of the lathe to be very strongly built, and the driving power extraordinarily great. The endurance of the cutting tools and of the important working parts could be gauged by comparison with lathes of less capacity after several months of constant use. There are other important factors, such as initial cost and of upkeep; these together should form interesting matter for the consideration of the management.

Undoubtedly there is a limit, to go beyond which would be to lose very rapidly.

TAP MAKING

Taps are made of a reliable brand of crucible cast steel, preferably steel of a tough quality, as specified by the makers, so that there will be no disappointment in the subsequent use after hardening and tempering them. In making a set of 1 in. Whitworth taps, three pieces of steel, $1\frac{1}{16}$ in. diam., will be cut off about $5\frac{5}{8}$ in. long, and annealed.

The annealing or softening of the steel must be very carefully done, the heat must be slowly applied until the whole mass is saturated or soaked through; also the degree of heat allowable must not be overreached. The proper heat is a dull red. After this the steel must be very slowly cooled by being covered with ashes, lime, or sawdust. [It must be remembered that if carbon steel is over-heated it loses much of its original toughness and frequently crumbles under the action of cutting tools, and will, therefore, not admit of a uniformly smooth finish. All appearing satisfactory, suddenly the tool commences to tear the metal in places, rendering it utterly unfit for the purpose.]

After annealing, the pieces are faced, centred, and roughly turned to shape, $\frac{1}{64}$ in. over size. There are two ways in which the blanks may be prepared. They may be turned to the required shape before the threads are cut, or the tapering may be done after the screw-cutting is completed. The reduced portion back of the threads (called the shank) is, or should be, universally regarded as the diameter of the tapping size, and it would be helpful to many if the actual size were stamped on *one* tap of each set. Usually a satisfactory finish may be obtained by an increased speed and a reduced feed, using a broad-nosed tool and lard oil for a lubricant.

When finished turning, the square may be milled, using straddle mills; two faces may be tooled at one setting. Instead of an ordinary carrier, a forked driver may be attached to the lathe face plate as shown for quick insertion of the tap and removal from the lathe centres.

Now, assuming that the screw-cutting lathe has a guide screw of $\frac{1}{4}$-in. pitch, the ratio in this case will be as 2 to 1, *i.e.* two revolutions of the lathe work to one of the guide screw; therefore $\frac{4}{8} \times \frac{10}{10} = \frac{40}{80}$, the wheels required. The angle of the screw-cutting tool will be taken from a screw gauge of 55°, and the nose of the tool rounded a little more than the threads on a standard screw of 1 in. diameter (see "Screw-cutting gauge," Fig. 137). If the saddle screw has dial-feed, the depth of each cut may be easily indicated. If not, however, a chalk mark can be made after each cut has been put on in the usual manner. It is not safe to allow the Vee groove to be cut on both sides, as the punishment on the tool nose is too great; moreover, the tool is liable to dig, and so spoil the screw. The leading side of the tool should do the ploughing, and after a few "cuts" the trailing side may be used to level up the shape of the groove. Calipers should be used to show the depth, and the cutting tool removed for the chasing rest to be secured. A standard 1-in. templet nut must be at hand, so that when the chasing tool has commenced to round off the tops of the thread, the roots, too, will also be nearly finished. Beginners should also gauge the diameter of the roots of the threads. Good chasing is an art. Chasing calipers must be used to test the outer diameter of the screw as the work proceeds. There should, of course, be a constant aim to press the chaser uniformly to the work. It will, however, invariably be found that after commencing to chase the pressure increases imperceptibly, and equally imperceptibly decreases as the cut reaches its extremity on the work, with the result that more is cut from the centre than the ends. Hence it is essential to make frequent tests with the gauging instruments, so that the work when completed shall be uniformly straight and up to standard size, both at the top and the root of the thread.

It is possible to be mistaken in chasing, and remove the metal in quite the wrong place. For instance, the chasing calipers and the appearance of the rounded tops of the threads both indicate a finish, but the screw gauge nut will not go on. Now, obviously, there is a tight place somewhere, and if the chaser were again similarly applied, the outer diameter of the screw would get a further share of cutting, but eventually the screw would be spoilt.

What is really necessary is the proper holding of the chasing tool to the work, and in this case it has been held too high, thus preventing the chaser points from properly cutting and thereby deepening the roots of the threads.

Students and apprentices will do well to test these remarks on some unimportant example, such as the making of a stud or axle. Holding the chaser too high prevents the points of the teeth from cutting to their full depth, but gives increased opportunity for the roots of the chaser to cut.

When the gauge nut has commenced to travel on the screw, but gets tight after a few threads, it should be removed, and the threads very carefully gauged from end to end of the tap. This cannot be too carefully done, and high places may then be chased down until the calipers or micrometer will pass with a uniform feel of touch over any part of the screw. This being done, the gauge nut will follow satisfactorily without any hard pressing or any slackness of fit. The milling of the grooves is the next step. There is a rounded cutter for the purpose. Three grooves are usually milled out, but Americans mill out four grooves, leaving much less thread on the tap, and, proportionately, less effort is needed to pass the tap through its work. After milling the grooves, a nut is passed over the threads to remove the rags or burrs, and a fine file in the grooves to finish off. The taps are all similarly tooled and hardened and tempered. In hardening, great care has to be given to protect the threads from burning; therefore an open fire has given place to a gas muffle, the temperature of which can be regulated as desired. When thoroughly hot, the tap is immersed in oil; this renders it tough, but too hard for use. It is, therefore, brightened in the flutes, and held in a hot tube until the desired colour appears, pale or dark straw, depending upon the quality of the steel.

Some experience is necessary to temper properly, *i.e.* not only the colour, but the length of the colouring must be uniform from end to end of the thread.

Chasers are sometimes secured in the lathe tool rest, but very great care is required in setting both in height and square with the work, a slight inclination of the cutting teeth to the right puts all the work on the first and second teeth. Similarly, the chaser inclined to the left causes the last of the cutting edges to operate. Further, the threads of the screws so produced will not stand erect, therefore for precise fitting work are unsuitable.

TURRET LATHE.

The turret lathe received its original name from the early types in which the tools were carried in a capstan head, or comparatively high form of turret. These were used only on the smallest pieces of work, such as watch work where the parts were generally of a repetitionary character.

Before this form of lathe could be used successfully on pieces of larger dimensions, the proportions of the vital parts had to undergo considerable change, also the method of construction. For a long time turning lathes fitted with an ordinary saddle and slide-rest, were occasionally supplied with a turret-head, instead of, or in addition to, the general equipment. This arrangement could never be made to work satisfactorily. A pivot bearing is not all that is required, and as an outcome by a very gradual growth we have arrived at a design which is shown in Fig. 147. The turret is a flat circular plate mounted on the surface of the saddle and connected to a controlling mechanism, the manner of attaching the turret to the saddle and the saddle to the lathe bed being the most direct and rigid, so that the cutting tools are under absolute control. The turret is turned automatically to each position the instant the tool clears the work on its backward travel,

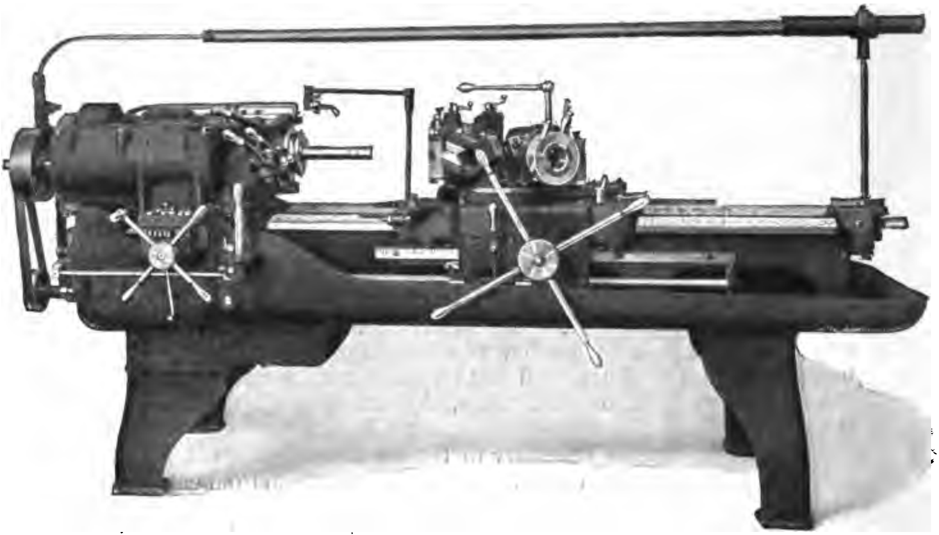


FIG. 147.—Hartness turret lathe.

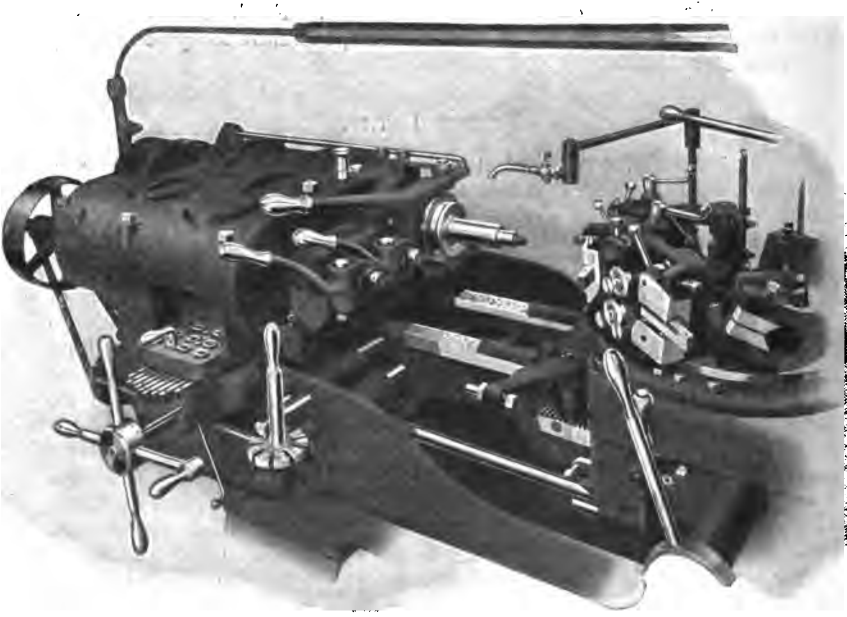


FIG. 148.—Cross sliding head.

and is so arranged that by raising and lowering trip screws near the centre of the turret, it may be turned to three, four, or five of the six positions of the turret, or any other division required by the operator.

The feeding mechanism for the turret slide and the cross feeding head receives its power through a speed varying device, which is under the control of the hand wheel at the head end of the bed. One revolution of this wheel gives the full range of feeds, from drilling feeds of 100 per inch to coarse turning feeds of 10 per inch, and every intermediate feed (Fig. 148) illustrates the fast-head feed gears, with the driving mechanism covered.

Cross Sliding Head

The cross sliding headstock is a unique arrangement. A power feed operates the head carrying the work relative to the turret tools.

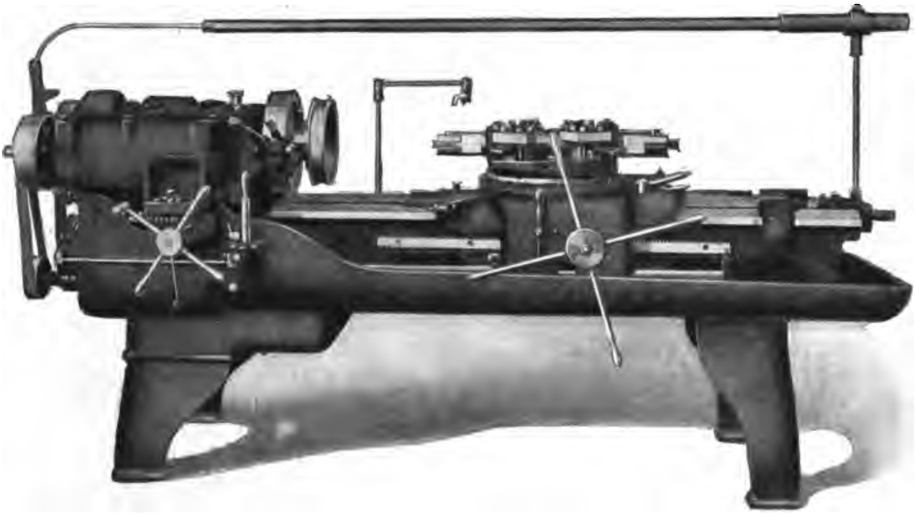


Fig. 149.—Lathe equipped for chuck work.

This arrangement permits of both bar and chuck work being tooled without special turret tools. The sliding head is gibbed to the guideways running across the machine, so that each tool may have a transverse feed across the surface of the work as desired. There are ten stops of varying lengths carried in a revolving holder, any one of which will arrest the traverse of the headstock. When fed by hand the pressure exerted is shown on a sensitive indicator. Fig. 149 illustrates the lathe having a wheel mounted in a chuck for machining all over.

DOUBLE SPINDLE FLAT TURRET LATHE

A further development of this type of lathe is to employ two spindles, each carrying a 17-in. jaw chuck for holding pieces of a duplicate character. The work is operated on by tools carried in a large square turret, each set of tools being duplicated, thus a pair of wheels may be chucked, and in the first position of the turret rough bored. At the second position of the turret the tools rough the inner side of the flange, the outer side and the face of the flange. At the third position the tools finish the above three surfaces of the flange. At the fourth position the holes are finished boring, and the outer and inner diameters of the wheels are sized by the finishing tools. In thus duplicating the tools on work of a similar character, the total time occupied is the sum of the time of all the operations divided by two. Therefore if two wheels are chucked, tooled, and finished in twenty minutes, the time for a single wheel is ten minutes, thus effecting a saving. This machine, originally designed to operate both spindles, may be used for work carried in one chuck and on work of a general character.

NOTES ON CHUCKING OPERATIONS

"The cutting tools for chucking operations, whether turning or boring, should have their rake or top slope sharp to the heaviest part of the chip. For instance, if a tool is to be used for facing a gear, the part that begins to cut first should be a sharp angle, so that the heaviest part of the chip should flow easily away, while that part of the cutting edge that leaves its mark on the finished face should take a shearing or angular shaping cut, which leaves the smooth surface. Perhaps there is no more important point to be borne in mind by any one wishing to know how to make a machine do its best work, than the cutting angles of tools. In a general way every one knows that a tool should have the least amount of clearance, and the greatest amount of rake consistent with the wear of the tool, but the man who makes the best record is the one who puts it into practice. The next point is that no tool should be allowed to project beyond its holder, or support more than is absolutely necessary. After having ground and set the tool properly, see that it has a chip or feed coarse enough to keep it from losing its edge in making thin chips. You may make the tool not only remove the metal, but cut it into fine chips having no special value. Even weak lathes generally do better work with a medium feed than a fine feed. It is not uncommon to see a very fine feed being used in trying to turn an extra true piece of work, with the only result that the tool does not leave an even surface. It alternately rides and 'digs in' with a very fine feed, when an even, steady cut would have been maintained by a medium feed. Chattering frequently occurs because the chip is not large enough to hold all the slack of springing parts. The cure for chattering is frequently more not less feed. Of course chattering may be caused by a cut that is just heavy enough to balance the weight of the work and spindle, and then the slight necessary looseness of spindle bearings gives the chance for chattering. An old remedy for this is to turn the tool upside down and thereby get the pressure down on the work. Chattering is destructive of the sharp edge of the tool and should not be tolerated. Facing cuts may be taken with tools made with round shanks, the advantage being that they may be turned so as to give the desired rake for free cutting. In

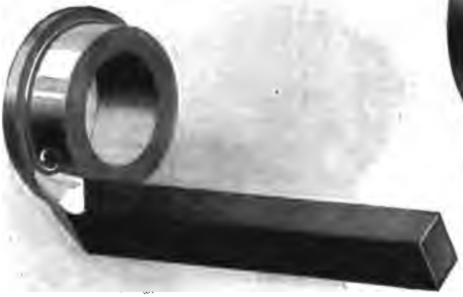


FIG. 150.—Turning to a shoulder.

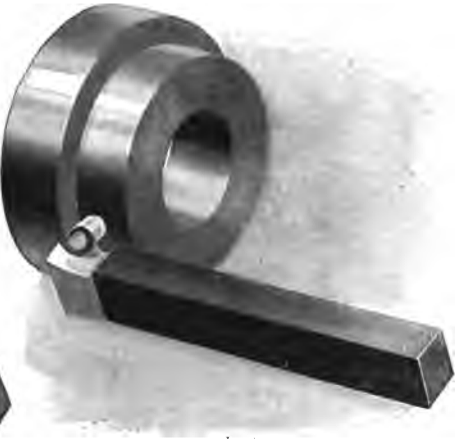


FIG. 151.—Turning an external shaving, showing rake of cutting tool.

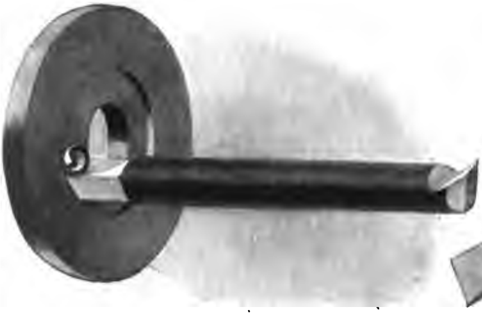


FIG. 152.—Facing tool cutting on disc.

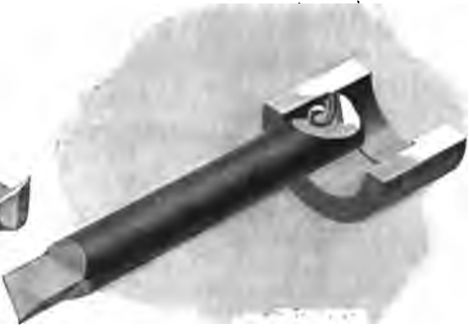


FIG. 153.—Form of tool for deep internal cutting.

facing make sure to take advantage of the convenient means of changing the speed, for a very important reduction in time of operation as well as the durability of the tool may be effected by keeping the correct cutting speed by simply shifting the lever one or more times as the tool is cutting. The failure to change the speed in this way involves the selection of an average speed, which is too fast at one part of the cut, and too slow at the other extreme. The fast cutting destroys the edge and makes a net loss of time when the grinding and resetting are included, and, of course, the slow cutting is also a needless loss which does not get a corresponding durability of cutting edge."

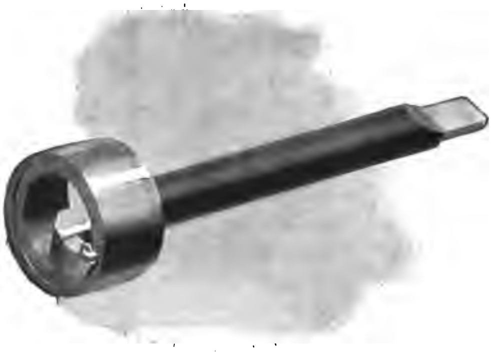


FIG. 154.—Facing tool operating on internal face of collar.

A facing tool taking a cut across the surface of a disc is shown in Fig. 152. In this arrangement there is no spreading of the cutting edge, the actual surface contact being at a minimum. A similar definite cutting action is shown on the boring tool (Fig. 153), and again in operating on the back surface of a collar (Fig. 154). To spread the same depth of cut over a large cutting edge would tend to push the tool from operating in a straight line, or to force the work out of the grip of the jaw chuck.

CUTTING SPEEDS

The velocity of travel of the cutting edge of the tools through the metal is called the cutting speed.

It is usually expressed in feet per minute, and varies from 8 to 200 ft. per minute in ordinary turning operations. With all other conditions unchanged the variation may be said to be almost directly dependent upon the size of the chip, or, in other words, the change in cutting speed does not change the weight of chips removable.

Slow speeds must be run for deep and thick chips, and high speeds may be run for the light cuts, an exception to this being in bar work, where the depth of cut makes a reduction of from 25 to 75 per cent. in diameter. This difference in diameter does not make a corresponding difference in cutting speed. For all such work the speed may be said to be effected by feed only. The other conditions that effect the cutting speed may be stated as follows:—

(*a*) The character of the work; namely, the accuracy as to size, shape and condition of surface. The quality of the metal to be cut. The quantity of pieces to be made.

(*b*) The quality, condition and shape of the cutting edge.

(*c*) The quantity and quality of a liquid cooling and lubricating medium.

(*d*) The stability of control of machine in forcing the tool undeviatingly along a path as nearly true as possible in order to minimise the edge-destroying lateral vibration that is ever present in the so-called standard machines and orthodox blunt tools.

(*e*) The practical period of endurance of the cutting edge. This period may vary 10 or 20 minutes in rough turning with quickly renewable tools to one or more weeks in accurate duplication of work with tools which are not conveniently renewable.

In machine-tool design many of these variants may be altered.

" In turret lathe work a tool should endure a sufficient length of time to allow it to complete two or more pieces in order to get the advantage of the accurate duplication for which the turret lathe is primarily designed. The length of the period beyond this point is varied according to the time required to put a sharp tool in the place of a dull one."

Another advantage in this type of automatic machine is that tools of a predetermined form may be made and adjusted so that a considerable quantity of similar pieces may be produced without any appreciable difference. This has been considerably improved by the use of modern high-speed steel, the cutting capacity of which is increasing year by year. Cutting tools will operate on bar work, forming pieces from the solid, and continue to hold their edge for several days without re-sharpening.

When one batch of work is completed the tools are withdrawn and gauged over or sent to the tool-room for inspection; in the meantime, a precisely similar tool can be fitted in the turret so that practically the machine need not stand for more than the actual time of re-setting.

Wherever practical " formed " cutting tools are used, that is tools of a uniform contour, these have a cutting edge which may be ground any number of times without altering the shape or precise dimensions of the product. An example of this type of tool, which is really a turned and ground disc, so presented to the work as to give the satisfactory clearance or relief angle. This system is a great advance on the forged and fitted tools, and where work has very sharp corners, and shoulders set down at precise distances, is of great value, because while the tool remains intact the product cannot change in form. It may be added that the setting of the tools is most minute and is generally accomplished to micrometer adjustment.

TURRET LATHE

Another form of turret lathe is given in Fig. 155. This is of a powerful construction and is capable of gripping forgings and tooling them at a rapid rate. In these lathes pieces such as piston rods may be tooled up to 3½ in. diameter, or work may be drilled, tapped, or bored and reamed. Taper work can also be turned with broad tools, and for repetition work having a number of diameters box tools are employed, which enable all the diameters to be turned at the same time. Handles and other work of curved outline is dealt with by broad-form tools.

Amongst other notable modern features there is a single-driving pulley, driven direct from the main shaft, thus doing away with the ordinary speed cones on a countershaft, or the machine may be driven direct by motor.

The motion to the spindle is direct through gears which are enclosed in an oil bath. The speeds are in gradual progression and may instantly be changed or reversed by lever.

It will be noticed that the surfaces of the bed are broad and those of the saddle or turrent base are long. The turret may be brought as required close up to the chuck without any overhang, thus keeping the parts rigid. On the back of each tool holder there is a check which ensures its correct location on the turret.

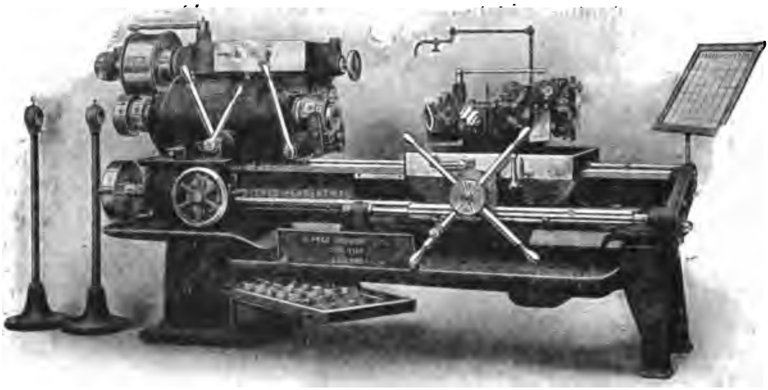


FIG. 155.

Binding pads are fitted in each hole so that drills and reamers can be properly held, or when slender work is being turned or formed bushes may be inserted to support it. The steel rack is fitted in an inverted position so as to be clear of the clips. The turret may be rotated in either direction or located at any position along the bed. On the disc attached to the star or pilot wheel for the turret slide an indicator is shown. This enables dead lengths to be obtained within the finest limits of error. Its effect is to ensure absolutely uniform pressure on the stops independent of changes of pressure on the cutting tools as they become dull.

Roller Steadies

With high-speed steel cutters it has been found that rollers, thoroughly hardened and polished and properly supported, have rendered possible a great increase of output, much in excess of anything which might be accounted for by the high-cutting speed alone. It has been found that by the use of roller steadies not only can the cutting speed be increased up to the limit of the cutter, but that the feed can be doubled, and even trebled, without any loss of accuracy or finish.

Hexagon Turret Lathe

To illustrate the increased production thus obtainable in the hexagon turret lathe, three separate tests were made on a mild steel bar 1½ in. diameter, reducing it to ¾ in. diameter at one cut, the object being to secure the highest possible output for each test. The conditions under which these tests were made were as follows:—

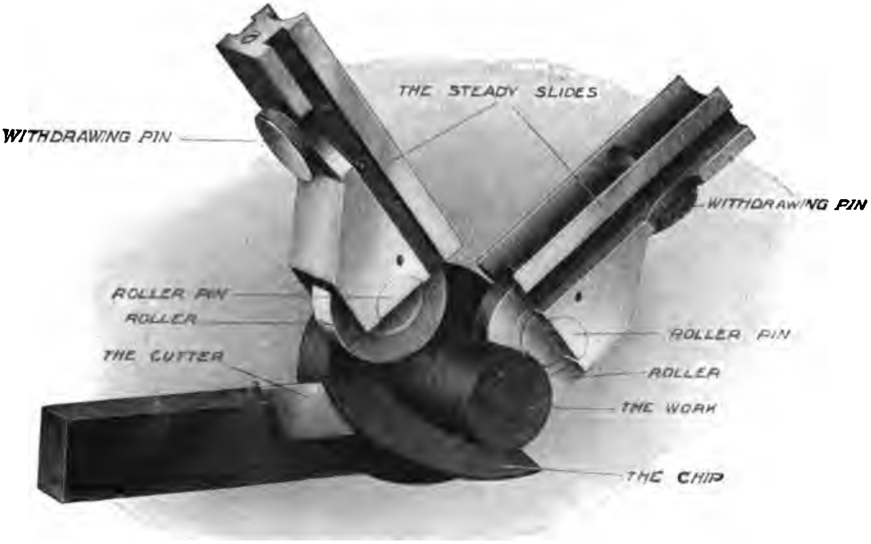


Fig. 156.

Test No. 1, carbon steel cutter and flat steadies.
Test No. 2, high-speed steel cutter and flat steadies.
Test No. 3, "special" high-speed steel cutter and roller steadies.

For each test the best combination of speeds and feeds to produce

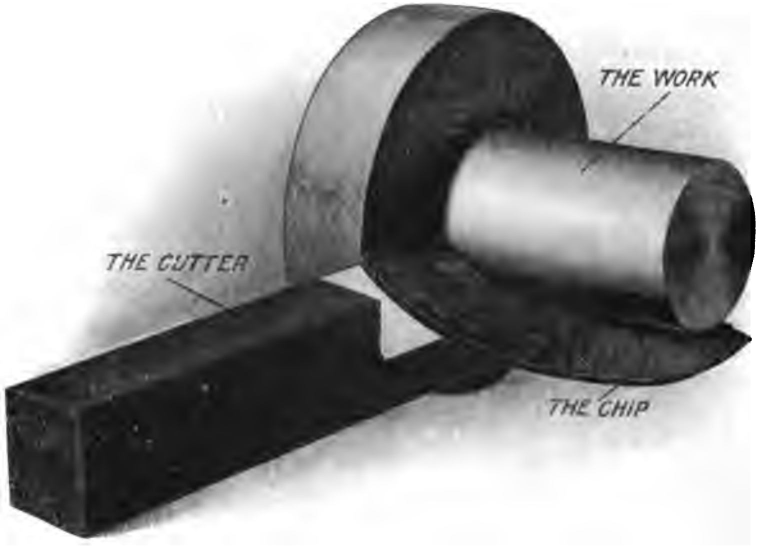


FIG. 156A.

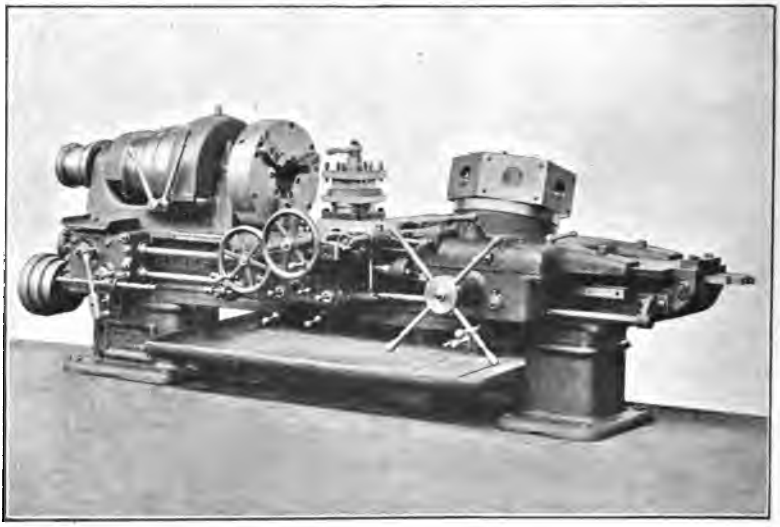


FIG. 157.—Heavy turret and traversing lathe with independent movements.

the maximum output was found before the test was begun. The following are the results of the tests :—

REDUCING A MILD STEEL BLACK BAR FROM 1½ IN. TO ¾ IN. DIAMETER AT ONE CUT.

Test No.	Cutter used.	Type of steadies.	Revs. per min.	Feed in in. per min.	Output lbs. per min.
1	Carbon steel	Flat	149	2·01	·753
2	High-speed steel	Flat	178	3·17	1·189
3	" Special " high-speed steel	Roller	470	23·5	8·8125

A 2 in. bar was also reduced to ¾ in. at a feed of 13⅜ in. per minute, the metal removed amounting to more than 10 lbs. per minute, and the resulting work being round, smooth, and parallel. This result from a single tool speaks for itself (Fig. 156; The Work, the Cutter, and the Chip, Fig. 156A). The above illustration shows the arrangement.

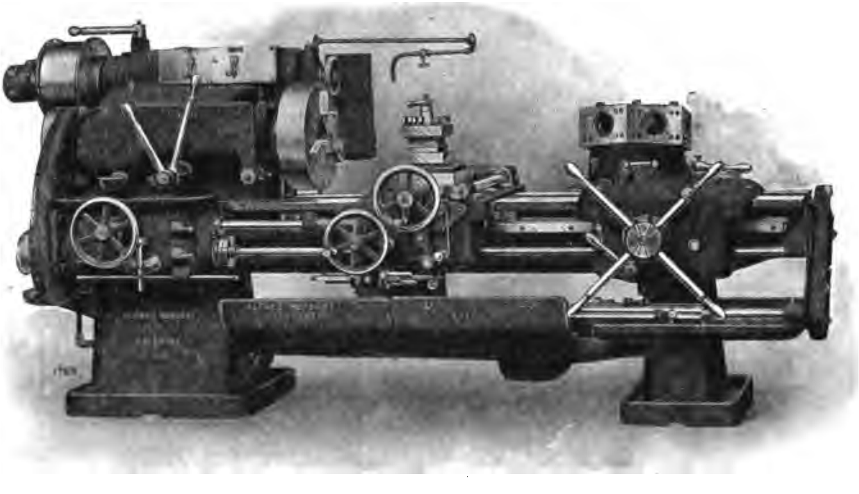


FIG. 157A.—Combined turret lathe.

A combined lathe, having saddle and turret, is given in Fig. 157. In this type of lathe, castings may be chucked and bored with the turret tools, while the cutting tools carried in the saddle-rest are operating on external surfaces. Fig. 157A is of a similar type but of less proportions.

AUTOMATIC SCREW MACHINES

In a small work of the character set out by the title given, purely automatic machine tools may be considered somewhat out of place; indeed, they deserve a treatise specially describing their various functions. We, however, have selected typical machines capable of doing work automatically which would otherwise need a skilled mechanic. A final example is given in Fig. 158, the automatic screw machine. Originally designed to produce very small screws and studs, it is now made in five sizes, the largest of which will cope with steel bars of 3 in. diameter. In the above machine the spindle is driven by two pairs of fast and loose pulleys on a back shaft.

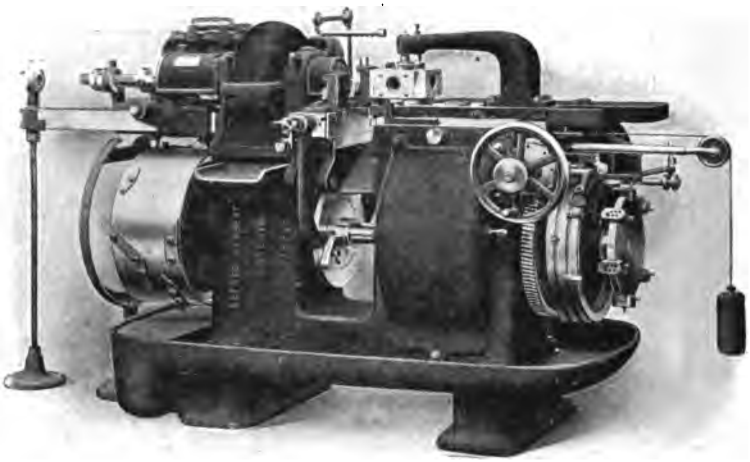


FIG. 158.

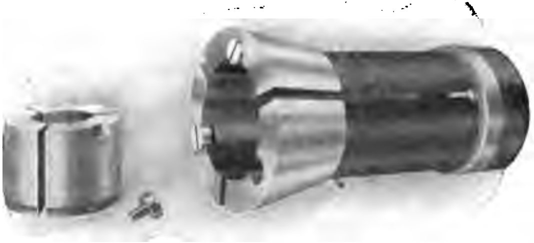


FIG. 159.

Two ratios of gears connect the shaft to the spindle, the low ratio being used for brass work, for work of a smaller diameter, and for high-speed work generally; the high ratio being used to give greater power for the harder materials, larger diameters, and heavier cuts.

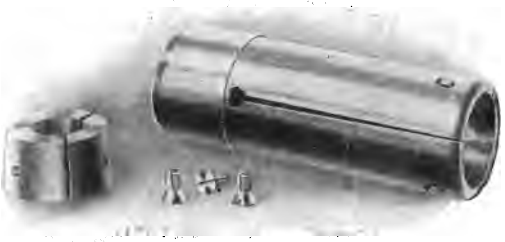


FIG. 159A.

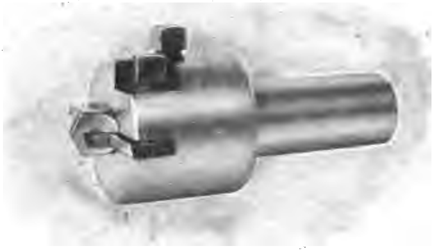


FIG. 159B.

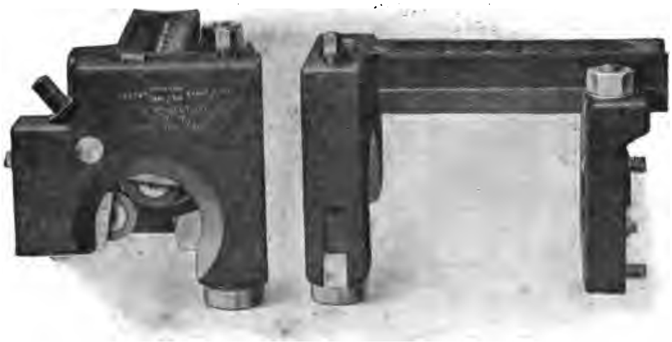


FIG. 159C.

To change the speed of the spindle automatically, the two belts which drive the head move separately, so that both belts cannot drive at the same time, the gear being so arranged that the belt forks are locked in position after changing until the next change is required. The belt forks can be set to give either two speeds forward, or one speed forward and one backward.

When screwing or tapping, it is necessary to use a much slower speed than when turning or drilling, and the countershafts are therefore arranged to vary the ratio between the two automatic speed changes, three changes of ratio being provided for each of the fast spindle feeds. Provision is also made for stopping the spindle at any required point in the cycle of operations. By stopping the spindle, tools can be withdrawn without spirally marking the work. One collet serves for all sizes of bars, removable liners being used. The liners can be changed without removing the collet from the spindle. The bar is fed forward by a feed collet, which grips it frictionally. A selection taken from a set of standard tools is given in Figs. 159, chuck collet and liner; 159A, feed collet and liner; 159B, centring and facing tool; 159C, inverted roller steady box; 159D, roller steady ending tools; 159E, Coventry self-opening die head; 159F, spring dies; 159G, spring dies.

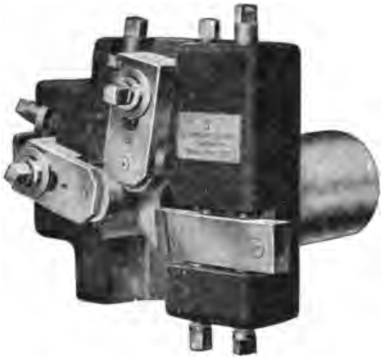


FIG. 159D.

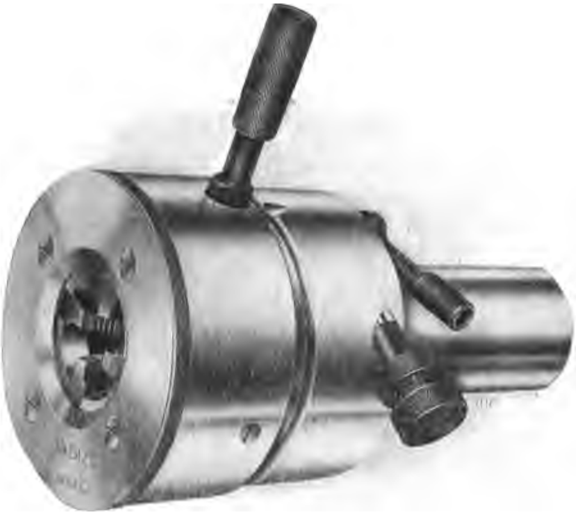


FIG. 159E.

The cams are designed to do all ordinary work without alteration. The self-selecting feed provides for all necessary variations in the feeds.

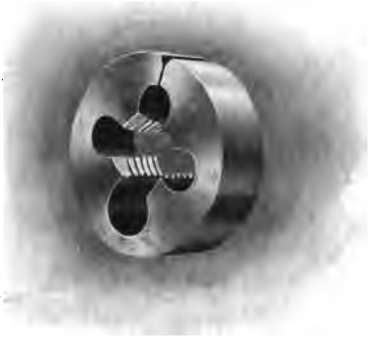


FIG. 159F.

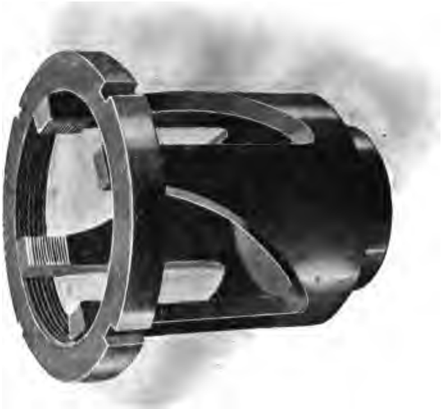


FIG. 159G.

LEVELLING AND SECURING OBJECTS TO BE PLANED

Securing work on the table of a planing machine is always a matter calling for the best judgment of the workman. His greatest care is to see that the work is firmly secured, yet without springing or bending any part whatsoever. The pressure exerted by the cutting tools is generally one tending to force the work off the machine table, therefore, in addition to the ordinary clamping arrangements, there should be stops driven into the holes in the table, or better still, bolted to it. Sometimes a flat bar is placed between the work and the stop to more evenly distribute the thrust. The manner in which the work is supported varies according to its size and shape. Long and slender pieces are frequently held without clips, being secured as shown in Fig. 160. The special angle plates and blocks are a good fit on the tongue T, and the sides are truly planed up while in place in the Tee

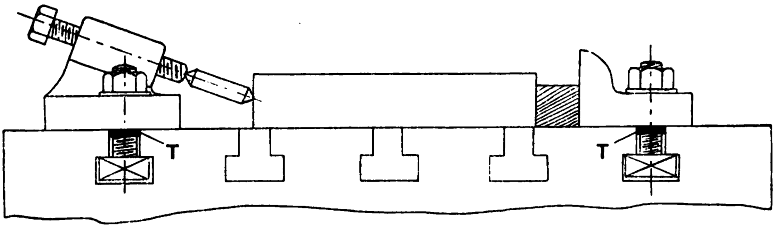


FIG. 160.—Method of fixing work on planing machine.

slots on the machine table; it will be seen that the setting-screws are placed in an angular position, and are provided with a conical hole at the end of each. The pins are made of steel and hardened on the points to prevent burring. In cases where the tooling of the upper surface will permit, the work may be secured by the pins forcing it directly on to the angle plates, which act as a true "wall," then when one surface is planed the piece is given a quarter turn, the machined face is placed against the "wall" and a cut is taken over the second surface, and so on, until the whole of the four sides have been tooled. The pointed pins should be of a uniform size and length, and should touch the work in a line parallel with the base. Secured in this way, rectangular bars may be tooled without bending or distorting them to any serious extent. Before attempting to secure any piece of work it should be padded up from beneath. A somewhat similar plan is given in Fig. 161, but without the pointed pins.

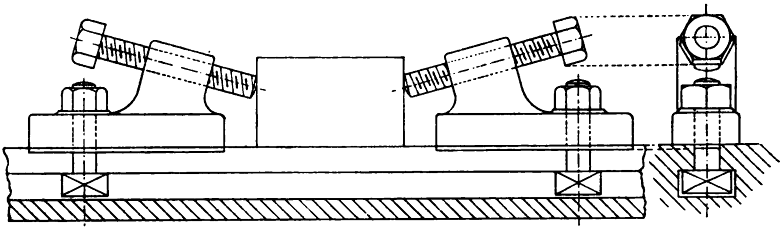


FIG. 161.—Method of fixing work on planing machine.

BLOCKING UP OR LEVELLING

Padding strips of flat iron or steel and thin strips of tin and of paper are freely used to support the work, whether of a slender or medium section. All surplus material and burrs are first removed, and the work, after straightening, is laid on the table of the machine; a general survey quickly shows which parts are really in contact and which require strips to make proper contact. This applies to work held in the manner above described, also to heavy iron castings and forgings which must be rigidly clamped down with bolts and clips. Screw-jacks are a very useful and satisfactory appliance to support parts not touching the table, and in this connexion bolts of various lengths, but having two nuts, may be conveniently used for jacks (Fig. 162). An example of the use of these occurs in supporting the body of a slotting machine, or a vertical milling machine, while the castings are turned on their backs during the planing of the vertical slide-ways. Large parallel blocks of planed cast iron are here in request, on which the casting is rested or secured (if practicable); failing these, huge blocks of timber are used, but these have to be very carefully fixed and wedged, and set so as to form a solid base for the work. Instead of mounting these heavy castings and traversing them on a weighty table past the cutting tools, planing machines, having one side open, are now frequently used. In such cases the work is generally stationary, and the tool caused to travel, but an open-side planing machine may have a specially strong cross-rail, well braced from the vertical standard, and, thereby, be quite rigid; here the travelling table is used, but this is further supported in its work by an additional rolling table, so that very wide body standards and other massive work may be tooled. Wherever it is practicable, a stout angle plate is fixed, so as to take the thrust at the end of the work. There may be need for two such plates, with substantial blocks or bars filling up the space between them and the object to be planed. Great care should be exercised in this fixing, as any undue hammering may cause even heavy castings to spring, or the plate to buckle. It is very necessary to make frequent tests of the truth of the table surface, as the driving of stops and other rough usage will prevent tooled faces lying evenly flat when it is necessary to place them face downwards. Similar care must be given to the angle plates which can very easily be sprung "out of truth." It is more often a careless manner of fixing the bolts, rather than actual pressure exerted in securing the work that causes bending. A bolt should always be evenly clipped beneath the head, also beneath its nut.

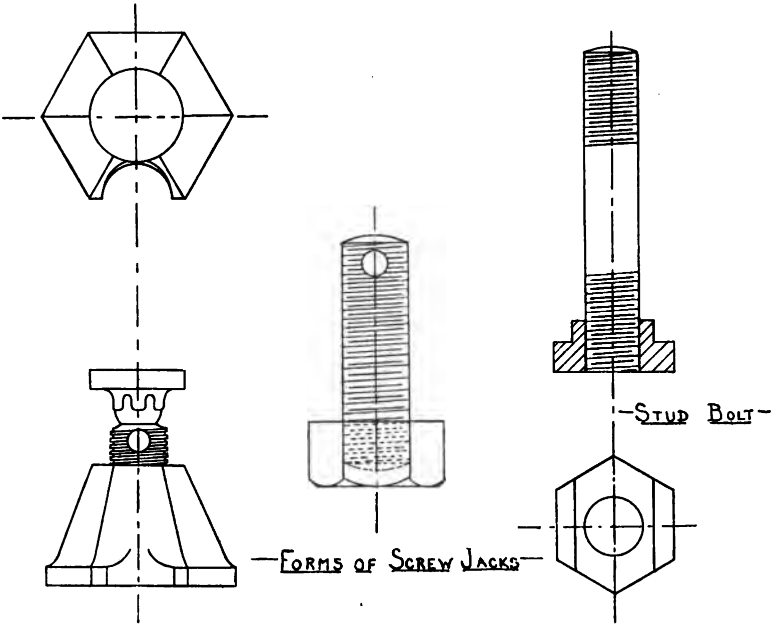


Fig. 162.

An example of holding a rectangular plate by means of special wedge-shaped clips is given in Fig. 163. The work W is firmly gripped at the sides by the wedge-shaped clips, the latter being well backed up by the two outer clips as shown. The stop S prevents end-thrust, and is sometimes supplemented by an end bar across the table. The upper face, being quite free, may easily be gauged over, and can be temporarily fastened by clipping the top until the side clips are properly secured. The casting, when practicable, should be laid on the planing machine table with the broadest of the tapering sides (*i.e.* caused by the draft of the pattern) at the bottom. By fixing in this manner the plate is less likely to lift a little, but if this is not practicable, the clips may be caused to force the work downward by raising the nose of each before finally fastening.

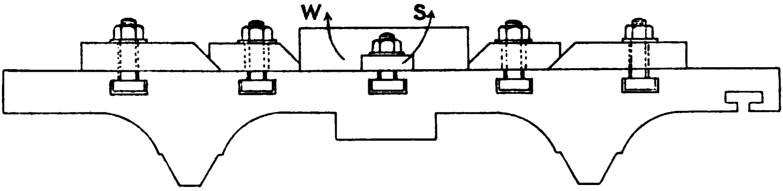


FIG. 163.—Method of fixing work on planing machine.

It must be remembered that, however uneven the under surface may be, packing strips must be inserted until the work properly rests at all points. The thinner the work the greater the care in setting. It is obvious that any movement of the work while the cutting tools are in operation may instantly spoil it.

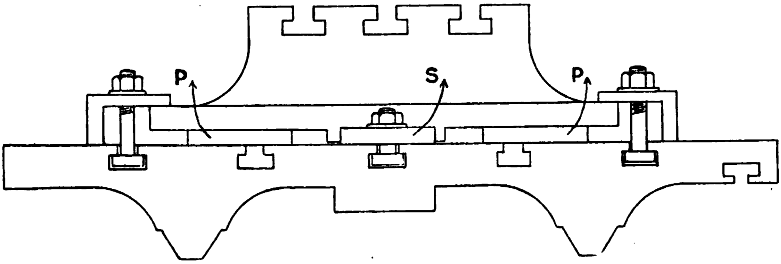


FIG. 164.—Method of fixing work on planing machine.

A simple case of securing a heavy casting is shown in Fig. 164; a series of side-clips are necessary to hold the work down on the packings P, P. These, however, are fixed *wrongly*. It will be noticed that they are placed too far from the ends, *i.e.* away from the holding down bolts. The principle should be to support the work just beneath the holding down clips, while the bolts should be located as close as is practicable to the work.

GANG PLANING

The growing practice in British machine shops is to specialise. All machine parts of a repetitive character are now, where practicable,

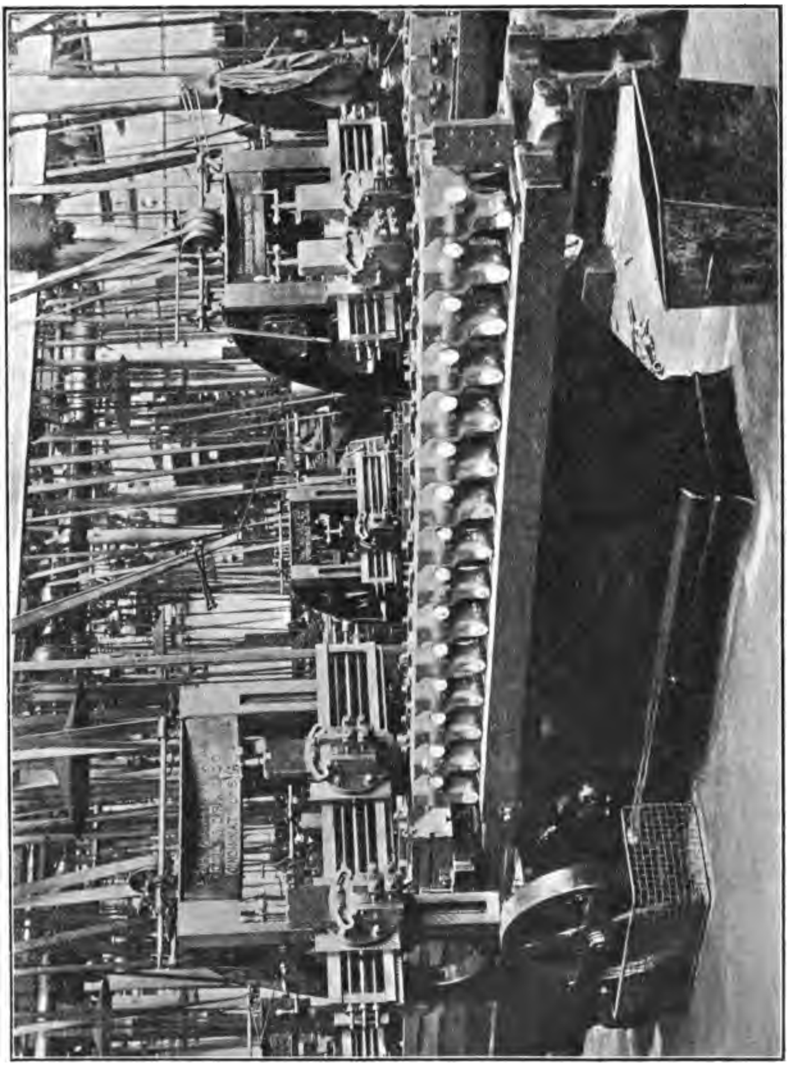


FIG. 165.—Gang planing—15 turret lathe aprons.

grouped in sets alike for planing, milling, drilling, punching, etc. The methods of securing and tooling the parts often shows great skill, because the principle is not only machining to gauge, but making the parts perfectly interchangeable. Some examples of gang planing are given below. Fig. 165 illustrates a gang (15) turret lathe aprons mounted on a planing machine for planing the slot in which the screw cutting nut slide fits. The castings machined in this way are at once interchangeable, a task rendered less difficult by the system of limit

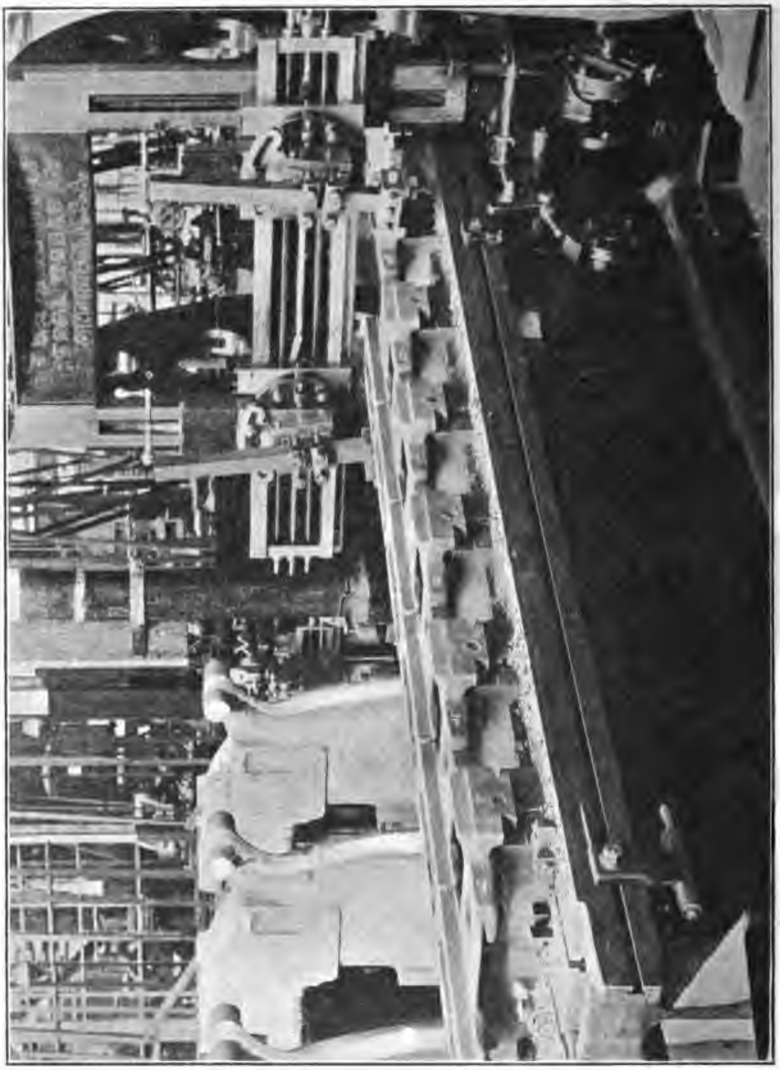


FIG. 166.—Gang planing—turret lathe saddles mounted in special fixtures.

gauges. After tooling the parts are assembled at the bench, and made so that the gauge will slide freely in each slot. Then when the screw cutting nut slide has been similarly treated, any two may be taken and assembled with no necessity for trial fitting, or need of subsequent correction. Fig. 166 shows a number of turret lathe saddles, mounted in a special fixture on a planing machine, for planing the part which

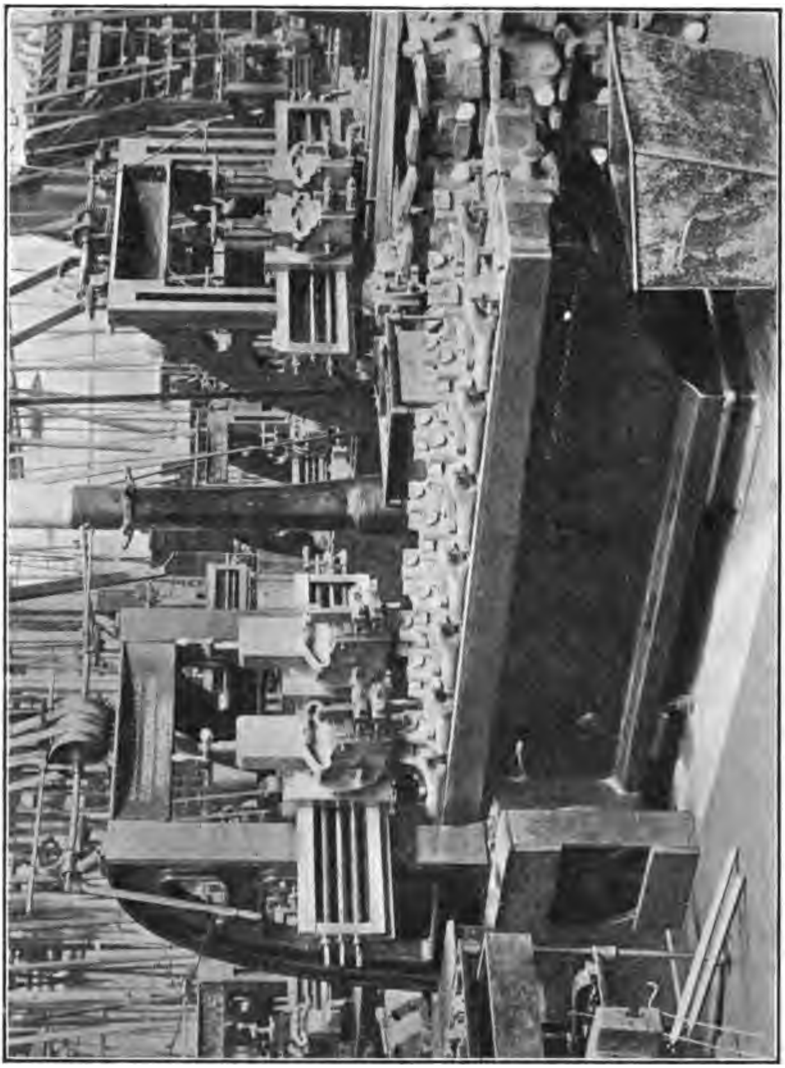


FIG. 167 —Gang planing—capstan lathe headstocks.

fits the bed. The work is set square by the fixture being located by the cross slide portion which has been previously planed at another

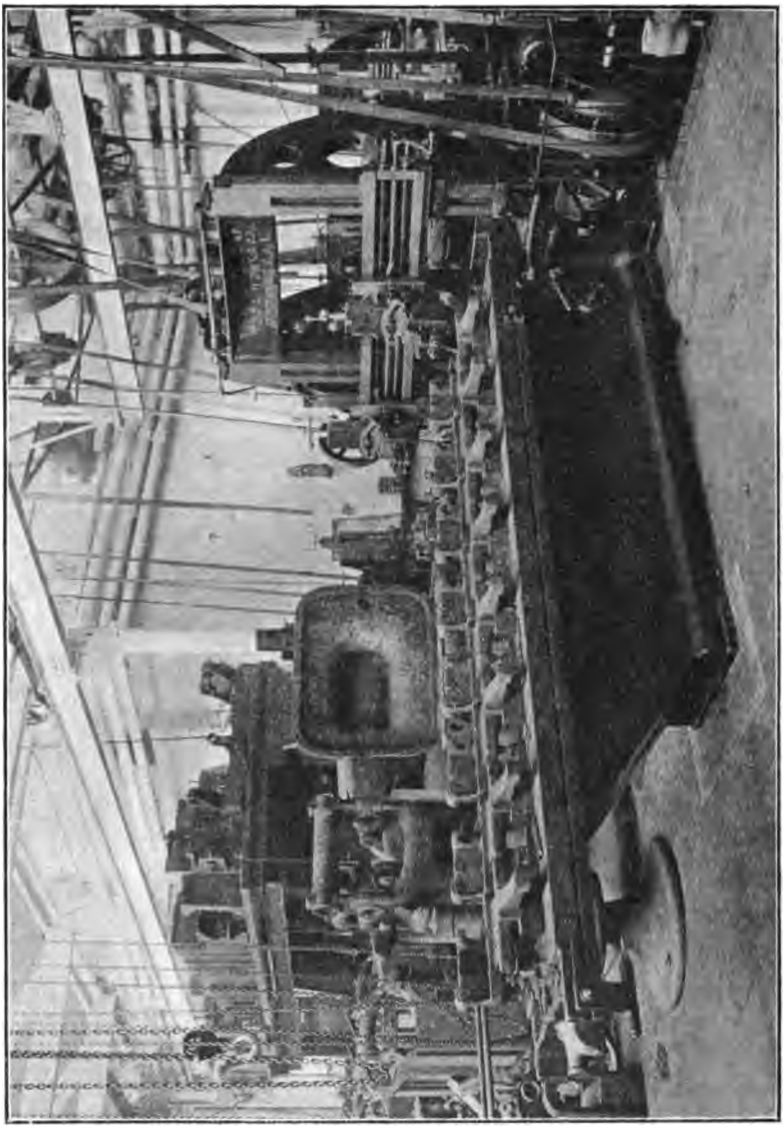


FIG. 168.—Gang planing—lathe headstocks.

operation. This example is a good illustration of the use of jigs, six of the saddles are in view, each being housed in a jig, and retained by the Vees which were tooled previously. It will be noted that the machine carries two stout tool-holders with sets of tools, each side of the work being cut at the same time. This duplex cutting also extends to the work's upper surface. Then with the tools set to gauge for the inner surfaces, the task of actual machining is considerably reduced.

Gang planing is also given in Fig. 167, where a number of capstan lathe headstocks are set in a double row for tooling the faces on which the bearing caps fit. Although the surfaces to be tooled are short, yet by placing a considerable number in a double row two tools are operating at the same time, thus effecting a saving on doing a much less number on a "shaper or a mill."

Fig. 168 is a somewhat similar example to Fig. 166, each casting being a lathe saddle and fitted in a jig. The use of jacks as adjustments and supports is clearly shown. The eight saddles, which occupy the full length of the table show the economy in this arrangement, and proves that the system has points of great advantages over that of building machines in much smaller quantities.

IRON CASTINGS

For general engine and machine castings the patterns are made of the best yellow pine, but in some special cases, and for delicate parts, mahogany is used. The wood must be dry and well seasoned. After finishing the patterns are usually coloured red, excepting where the holes or cores are to be made; these parts of the pattern are made to project, and are called "core prints," and are painted black. Heavy body patterns are coloured in the reverse order. The cores are of dry sand or loam, and are made in boxes, the internal part of which has been tooled out to the precise shape the core is to be. On removal from the boxes the cores are dried or baked in an oven; when removed they are hard. It is necessary for the cores to be firm, so as to resist the flow of metal, which then circulates around them. To ensure that the patterns, when finished and placed in the hands of the moulder, will correctly leave the sand, or in other words, to enable him to take a perfectly correct copy and produce an impression, *i.e.* a counterpart in iron, it is absolutely necessary for the draughtsman and the pattern-maker too to possess a thorough knowledge of this part of a moulder's work. They should also clearly know how the pattern may best be moulded, also which parts can be secure and which must be detachable for the moulder's convenience. In moulding, the process is briefly this, a rectangular "box" or "flask" is used, this box has neither bottom nor top, but a simple frame with a series of ribs or webs within, to hold the sand firmly as it is "rammed" in the mould. A similar box can be fitted over pegs on to the lower one, and one half of the pattern may be moulded in it. For thin castings the pattern may be placed on a board, and the box placed above it. Then suitable sand is put in and rammed until it is full. The box is next inverted and the board removed, a coating of facing sand is put on, and the upper box placed in position and filled as in the previous case. It is very important to see that after the pattern is removed the boxes join precisely, and remain in proper position until the molten metal has been poured. A hole is made in the upper face, and a channel is cut for the metal to flow to the mould.

There has been a considerable advance made in the method of producing high-class iron castings. Small machine parts for repetition work, cylinders for motor engines, gas engines, and in cases where nothing but the best possible production will suffice, all have largely contributed to this improvement.

Special patterns have been constructed, moulded and castings made, and wherever machinery would improve them they have been tooled and made into permanent patterns themselves; venting the cores has been improved by the wax wire core vents.

The general ironfounder no longer caters for all classes of work from his one cupola, but the finer mixtures of iron for specific work has given exceedingly good results, and this, together with the improved pattern, and the special care and appliances in moulding, have made it possible to produce a batch of cylinders perfectly true to pattern and comparatively very thin, but without any trace of a flaw. Moulding is thus the work of experts in the art.

Work thus produced, each part being alike in contour, has made it possible to design, construct, and use holding appliances, which could be set accurately, say for the first of a large quantity of similar pieces to be machined, and remain in the proper position until the whole of the work was completed.

The following advantages may be added to the above: (1) Reduction in the weight of the castings owing to the uniform distribution of the metal, especially in work to be bored. (2) Reduction in the amount of metal left for tooling; hence (3) a reduction in the actual time required for doing the work. (4) Subsequent setting reduced to a minimum where "jigs" are not used, and the same remark applies in some forms of holding jigs where there is a margin allowed for adjustment by set-screws. Another form of pattern is to cast half the pattern on to a plate. This is called plate moulding. The mould is completed by placing the pattern equally between two boxes; here, again, the union or joining must be perfect, or the error is at once marked on the casting produced. In the best work so cleverly is this joint made, that the castings are made without the customary "flash" or "fin."

MALLEABLE IRON CASTINGS

Malleable iron castings are a distinct speciality. The castings are moulded from patterns and cast in a similar way to ordinary iron castings.

The castings, however, are made from a special mixture of mottled iron and hard scrap, the best results being obtained by melting the above in a crucible. The product is then thoroughly fettled, and all traces of sand removed. At this stage great care is exercised, because the articles are very hard and brittle, exactly the reverse of the condition of the final product. The castings are then ready for annealing, a process of softening by the agency of heat, the castings being packed with red hæmatite iron ore in an oven or muffle. The muffle is sealed and slowly heated until the castings have reached a dull red heat, viz. 1200°F. to 1800°F. At this temperature the muffle is allowed to cool down slowly. The time occupied by the process varies considerably, 50 to 80 hours or more, the time being proportional to the size, *i.e.* bulk of the articles subjected. The structure, and the whole nature of the material is now changed or converted by being partly "decarbonised." Good malleable iron castings are very steely in appearance and behaviour. They may be used in many cases equally satisfactorily with forgings of W. I. or M. steel, and will admit of being twisted or bent double without showing any fracture. Much, however, depends upon the thorough penetration, and of the changed condition of the product, *i.e.* it should be homogeneous. In machining, the cuttings will curl similar to steel, and if lubricated the metal will show a lustre like polished steel. The cutting tools should be keen, say an angle of 60°, and allowed a slow feed, the speed may be higher than for wrought iron if the articles have been thoroughly annealed. Castings which are not thoroughly treated are useless, since they are altogether unreliable where ductile metal is essential.

Notes on Materials—In Relation to Cutting Tools

Before commencing to cut or reduce to dimensions given any piece of material, it is essential to know something of its characteristics, that is to say, whether it is hard or soft, whether it is tough or brittle, and to note the amount of material allowed for tooling. The shape of the object, its distance from the tool support, and the method of fixing and securing adopted are among the reasons we have for selecting a cutting tool of a certain kind and shape.

Cast iron is brittle, granular, and has a hard skin or scale, which must be removed before the iron can be cut freely. It varies in hardness according to requirements and the thickness of the metal to be cut. Wrought iron and mild steel are fibrous with but little scale; these materials are not brittle but tough. Forged mild steel increases in hardness proportionately as the carbon in it increases. Cast mild steel is not always uniform, sometimes very hard, at others comparatively soft; small pin holes are also frequently a source of trouble. Tool steel or crucible cast steel is richer in carbon, it is therefore very brittle, but also very strong, and may be hardened and tempered to any degree.

The addition of certain chemicals, such as chromium, tungsten, or molybdenum, renders it much harder still (see "Steel Manufacture"), and makes it of a permanent hardness uniformly throughout each bar. The above steels are very fine grained. Phosphor bronze is hard and very tough, composed of copper and tin with a little phosphorus. There is considerable experience required to make this alloy. Gun metal is much less hard and less tough than phosphor bronze;

it is composed of copper and tin. Brass is generally soft but tough, composed of zinc and copper. Copper is tough and fairly soft. Deposited copper is tougher still and thoroughly uniform. Lead is tough but very soft and plastic.

Now from the foregoing, it is, I think, evident that to machine, some of these metals must have their grains or atoms separated, and others must have their fibres cut, also that a tool suitable for breaking up granular metal may be quite unfit to cut cleanly into a fibrous material, and the converse. As a general principle we may say that the harder materials, requiring more penetrating than the softer ones, can be attacked with tools having obtuse angles, the cutting edges of which are well backed up with a good body of steel, while the softer materials are found to yield best when penetrated with cutting tools having acute angles, but whose cutting edges should always be supported with as good a body of metal as is consistent with the angle of the tools. The first essential is that the base of the tool lies evenly on its support; what we have always to bear in mind is that "chatter" or "vibration" is the great enemy to all good cutting. The tool, therefore, must be fixed on supports as near to the cutting edge as is practicable. This is exemplified well in modern turret lathes, where there is practically no overhang, each tool being controlled or housed right close up to the cutting edge. In some cases these tools are correctly formed to the shape of the object, and the breadth of their cutting edges is often much in excess of their depth or length. This plan of securing has made turret lathes the great success we find them to-day. Therefore rigidity and the nature of the materials are to be understood if successful cutting is to be accomplished.

Knowing the behaviour of the material when attacked, we may get the most suitable tool for each. Another point in this connection is the proper lubricant, and the rate of feed or traverse. Generally wrought materials are best cut when lubricated, but hard steel is frequently an exception, this, however, is not always better cut with a lubricant, but it will finish to a lustrous surface *only* when lubricated. That is, a finishing or scraping cut must be lubricated to obtain a good surface, even though the material lurched or tore up during deep cutting.

Much depends upon the brand of steel cut, upon the quality of the steel tools, and the position at which the cutting edge is made to approach the work, also the capacity of the machine.

PREPARING BARS FOR MACHINING

Generally bars of iron and steel have to be cut to approximate lengths before they are machined. The original practice was to cut bars of small section partly through, and finally sever them by hammering the nicked part over a hole in the anvil or the edge of it. Larger bars were first heated and cut off with a hot set. Bars cut in this primitive manner necessarily had to be left a little too long, so that they might be cut smoothly and to precise length in the lathe, shaper or other machine tool. There was more or less distortion of the bars in cutting off, but at that period deeper cuts had to be taken, owing in part to the above and partly to the irregularities caused by poor rolling. This has given way to the practice of machine-dressing the bars direct, either in a cutting-off machine with a single-pointed cutting tool, or by means of a power sawing machine with a flat blade called a hack-saw; but a more successful cutting blade is the circular saw, which is capable of cutting through a shaft at the rate of 2 in. or more per minute; the hack-saw cuts at the rate of 1 in. per minute. A novel device for driving a circular saw is a machine which is provided with a saw having a sprocket drive, the sprocket wheel engages with radial slots in the blade, thus making it a sure drive. Another special feature is that every alternate tooth is bevelled, and made $\frac{1}{64}$ in. higher than the finishing tooth. The makers contend that by so doing the chips are allowed to flow more freely on the sides of the cut, which prevents them from clogging between the teeth, and, therefore, a more rapid feed can be maintained without increasing the danger of dulling the cutting points. In this connection of cutting off, mention may be made of an abrasive metal cutter, which is really a high grade carborundum wheel 12 in × $\frac{5}{32}$ in. running in a machine at 4000 revolutions per minute. This is found to be capable of cutting through a bar of $\frac{1}{2}$ in. section high-speed steel, perfectly true and without burrs in ten seconds; otherwise the bars were fractured by hammering and the ends ground truly afterwards. Two operations at a much slower rate.

MACHINING ALUMINIUM

Aluminium is very queer stuff to cut; with ordinary tools the metal either clogs the tools or causes them to dig in, tearing or gouging the material, leaving a very uneven surface. In turning aluminium the tools should have plenty of top rake and bottom clearance. A thin, tapering tool made with a keen cutting edge, and well sharpened on an oil-stone, gives excellent results. This keenness of cutting edge applies also to all kinds of cutting tools for milling, and for drilling purposes too. To wash away the cuttings, and obtain a smooth finish on the work, a good supply of soap and water must be freely used. In milling it is found that coarse-end mills of a small diameter give satisfactory results.

In polishing aluminium a buff or mop is used, the wheel being sprinkled with finely-powdered tripoli; but a rag buff or mop containing a sprinkling of rouge will give a brilliant lustre to the surface of the work.

By slowly heating this metal to a temperature of 600° to 700°, and gradually cooling articles which have become hard in working, as in press-tool work, they will be thoroughly annealed. Great care must be exercised to obtain a uniform heat, as the metal becomes plastic and will quickly change its shape if made too hot at any part.

In tooling, since the material yields satisfactorily when high speeds are obtained, less depths of cut should be given. Heavy cutting will bend or otherwise distort this material. For the above reason pure aluminium is difficult to operate; but when alloyed with bronze we get a much more durable product, especially when parts have to be bored for shaft or spindle bearings.

ORIGINAL METHODS OF WORKING

It seems to have been long known that the cutting capacity of a single-pointed tool for turning and planing depended upon its shape, position of approach, angle, depth of cut, amount of surface contact, rate of speed, and rate of feed. Keen interest was also taken in selecting the tool steel, also in subsequently hardening and suitably tempering the cutting tool to make it stand up to its work.

On the other side there were two or three factors opposing. The nature of the material operated upon, such as hard and dirty castings of iron, or want of homogeneity in the mild steel bars, but the greatest defect was in the sparcity of metal in the machine tools. For the most part lathes were weak in important parts, gears were narrow and uncut, small lathes had large gaps to accommodate big work on thin plates, speed cones replete with many steps, and very narrow belts driven from the main to countershaft pulleys equally narrow; beds, spindle and poppet springy. It will, therefore, be seen that the machinists were limited in many ways of increasing the output, in fact, the procedure to-day scarcely resembles that of the days before the advent of air-hardened or high-speed steel. Then it was a frequent occurrence to see stout new belts destroyed in a few days on a piece of work that, were it to be tooled to-day in a modern lathe of same height of centres, there would be no difficulty whatever; moreover, in a given time two, three, or more similar pieces would be treated with comparative ease. Before commencing the subject of milling, and of gear cutting, which are more truly examples of the copying principle, some reference may be made to the necessity of accurately constructed machine tools.

COPYING PRINCIPLE

"Copying" is understood to mean in machine tool construction the production of plane and angular surfaces, and of curved and cylindrical surfaces.

(1) That a planing machine table upon which flat pieces of work may be supported and carried past a fixed cutting tool, mounted in a tool box, and fed either in a horizontal or a vertical direction, should be straight from end to end is naturally expected, hence the word "planing." But a little reflection should show that the machine table is only flat and straight, as a result of the true cutting of the tools which produced it, and of the subsequent corrections by hand tools in addition to this (if necessary). To obtain a true copy of the cross-slide of the plane, the cross-slide itself should be fitted with a tool-slide capable of moving in a perfectly straight line across the surface of the machine table. To guarantee this absolutely parallel movement it is not

uncustomary for a light cut to be taken across a planing machine table by its own tool-slide after a new machine has been erected.

The evenness of a planed surface then is a copy of the surfaces of the planing machine which produced it.

(2) A lathe spindle revolving in its bearings is used to drive a shaft between the centres, the revolving shaft will be a copy of the spindle in its path, and however carefully it may be tooled it cannot be other than a true copy of the parts which produced it.

(3) In a similar manner the transverse slide fitting in the lathe saddle will move in a line at right angles to the "ways" of the bed only as a copy of the tooling of the saddle in this particular, when the lathe was constructed.

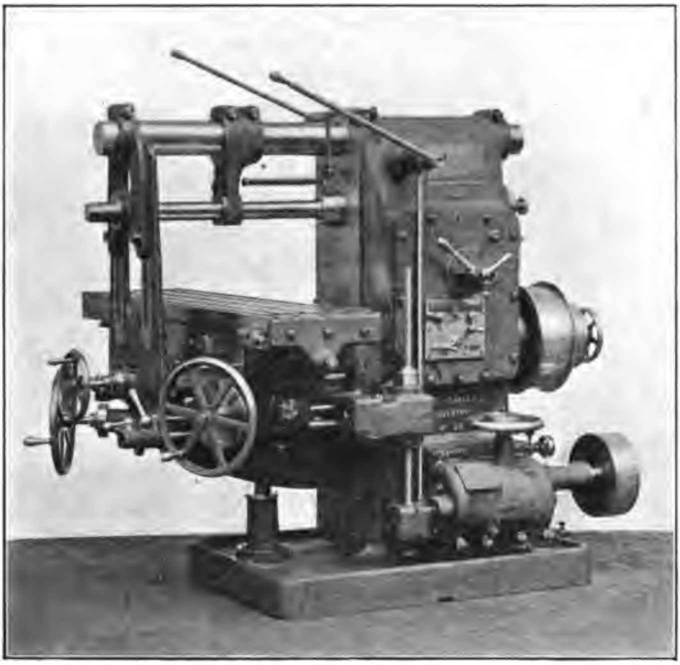


FIG. 169.—Modern horizontal milling machine.

(4) A drilling machine spindle will move in a straight line only as a copy of the alignment of each of the bearings which support and guide the path of the spindle.

(5) In like manner, a truly-bored hole made with a bar and cutter can only be produced when the spindle carrying the bar is true from end to end, and when it revolves in truly-bored bearings.

(6) Again, the table of a pillar drilling machine which supports the

work is perfectly at right angles to the axis of the spindle at every point in its surface. This is absolutely essential if truly faced work placed upon the table is to be drilled or bored at right angles to the given true face; this being so, the pillar and spindle must be quite in parallel alignment, also the bearing in which the table works or rests. To obtain this degree of accuracy the bearing for the table is finally tooled in place, being operated by a bar and cutter secured to the machine spindle direct.

FIG. 169A.

FIG. 169B.

(7) This principle is well exemplified in milling, where, for instance, a vertical spindle carrying on its extremity a large disc cutter is engaged in cutting true surfaces on pieces of work, parallel to the surface of the

machine table, or the same machine spindle carrying a vertical cutter, may be used to produce true surfaces on pieces of work at right angles to the table on which the work is secured.

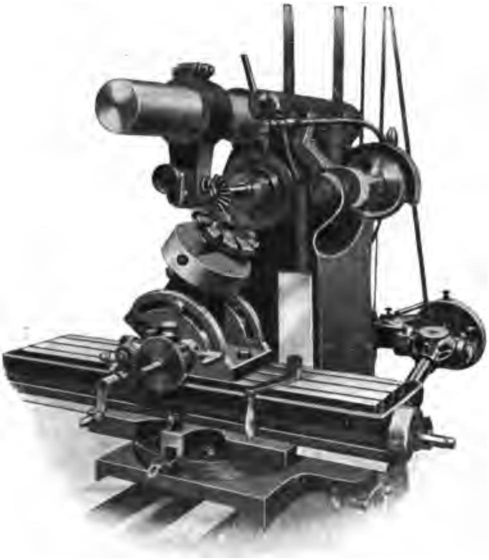


FIG. 170.—Milling. A gear cutter while held in chuck.

(8) Thus in horizontal milling we have a revolving cutter of a plain or formed pattern, the former will produce a plain surface, and the latter a counterpart of its own particular form. From this it will be seen that whether we consider planing, turning, boring, drilling, or milling machine operations, the work produced is at its very best only when the machine is at its best, showing clearly the great importance of precision in design and construction by the makers of the machine tools and of the care necessary on the part of each operative to get the very best result obtainable. To do this obviously means that the slides, screws, spindles, tables, etc., of the machines shall be kept clean, *i.e.* free from grit, and that all moving parts are periodically lubricated. It is also important to note that gibs and slides are kept in true adjustment, and in a similar manner moving shafts and spindles be under proper control in their respective bearings, *i.e.* they should be adjustable.

NOTES ON MILLING

The advantages of high-speed steel are seen very clearly in the construction of modern milling machines. Figs. 169 and 170A are illustrations of this. These machines are designed for heavy milling. Driven by a single pulley which runs on annular ball bearings, the friction is reduced to a minimum. The driving gears are contained in a box (Fig. 169A) which gives sixteen spindle speeds in either direction placed in geometrical progression, the changing being effected by sliding gears. There are two driving gears keyed to the spindle, and since these and the box gears are cut in steel and case hardened on the teeth they give a smooth and powerful drive. The spindle showing the above gears is given in Fig. 169B. All the gears are fed with oil automatically. Equal improvement has been given to the knee and its supporting slide and clamps. The bearings of the knee extend above the planed surface on which the saddle slides, thus giving it a long and ample guide, and a gripping surface to the column which adds to its rigidity. This is further improved by the arm brace. There is no machine tool except the lathe which has so great a capacity for different jobs, as the horizontal milling machine, with its various accessories. Among the pieces of work which it is capable of tooling may be mentioned engine connecting rods, including the eye or knuckle end of the rod, this part being tooled preferably with a pair of straddle mills of large diameter. The example having been previously sawn or slotted to get out the solid block will leave ample metal for the above mills to face up. Rods of a much smaller size, but which are forged without a fork, may be milled direct with a single cutter to open out the way, thus dispensing with the sawing or slotting out process. There are very powerful machines of the "Lincoln" type or of the "planer" type, in which case the cutter mandrel is housed at each end in bearings carried in standards, to be hereafter referred to. Referring again to the horizontal milling machine, spur and bevel gears, or screw gears are conveniently cut, also Tee, angular, and other forms of slots, can be cut out of solid

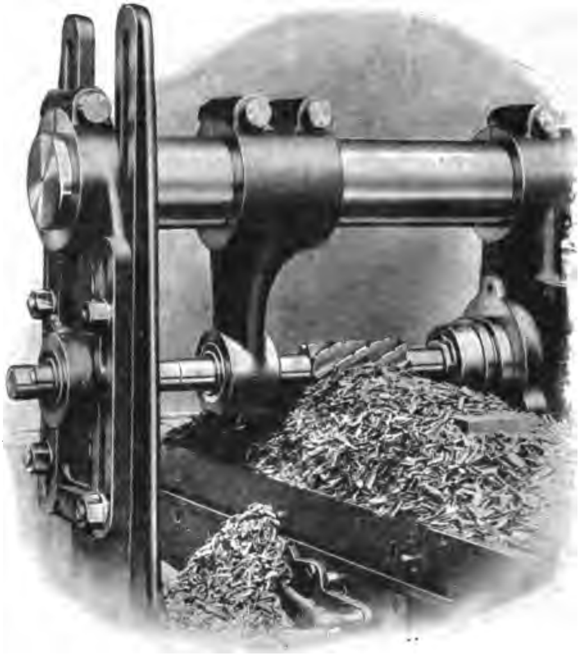


FIG. 170A.—Slab milling.

without the use of an arm brace. Milling cutters are also made on this machine, having straight, spiral, or formed cutting edges; twist drills are also cut, and shell and fluted reamers. Another case is that of cutting gear wheels, singly or in pairs. In the latter case, two distinct pairs of headstocks are secured side by side on the milling machine table, the gear blanks being fixed on their respective mandrels, and

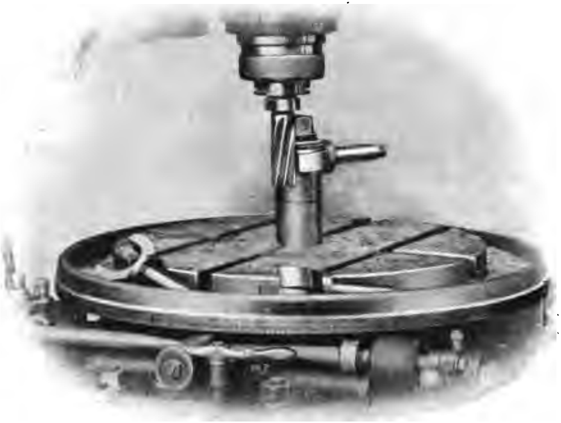


FIG. 171.

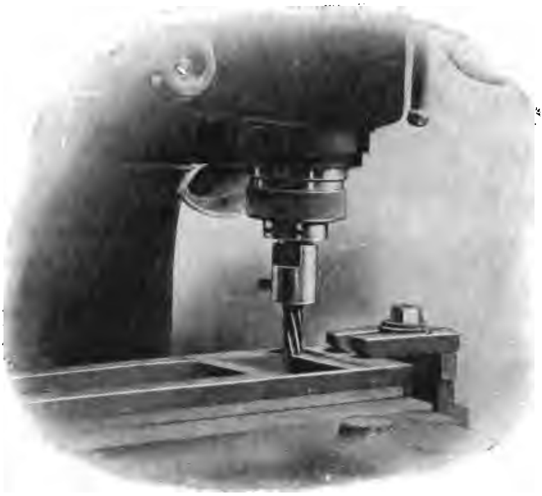


FIG. 171A.

mounted between the centres of the heads. In this way a great number of similar gears may be cut, the pitch and number of teeth being controlled by the master wheel. Unless the gears are of a coarse pitch the cutter takes the full depth at one cut; much, however, depends upon the rate of feed, and the condition of the cutters, and upon the general efficiency of the machine. There is no machine carrying cutters that demands more care and attention than the milling machine with its numerous cutters and appliances.

It should at the outset be remembered that usually there are several teeth of the cutter in operation at the same time, and that frequently the surface cut is a broad one, or made up of a number of surfaces, which in the aggregate is of a considerable area. Now, since a milling cutter is made up of a number of cutting edges, and each one capable of cutting off a comparatively small amount of metal, it might be supposed that the holding down force is just proportional to the size of the chip. This, however, is by no means the case, as would be clearly demonstrated by comparing shaping and milling chips from a given piece of work having the same depth of cut while held in a machine vice; of the two processes the milling would move in the vice first. It is, therefore, essential to note the actual surface contact of the tool, and to see that the work is firmly secured either in a good gripping vice or jig, or directly to the machine table. The cutter must be sharp, a good fit on its spindle, and when keyed must revolve truly. A dull cutter puts a great strain on its key, the mandrel, and the driving spindle, therefore, if a coarse feed is given, the work will either move or the cutter will jam and distort the spindle. There are a set of distance bushes supplied with each cutter mandrel, but if others are ever substituted they must be truly faced on each side. By this arrangement each cutter is held up to its work evenly at every point. The best position for the cutters is at the nearest point to the driving spindle. The upward edges of the cutter must meet the work, and the automatic feed put on after the cutter has commenced cutting. The pitch of the teeth of a milling cutter is decided by the metal to be operated on. Wrought materials, as in wrought iron and mild steel,

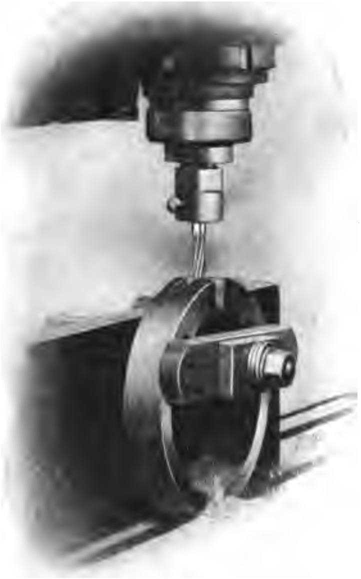


FIG. 171B.

also aluminium, should have a copious lubricant to wash away the chips as they are produced.

Cutters suitable for cast iron have notches cut at intervals along the cutting edges to break up the metal. High-speed steel cutters have considerable advantages; this is shown very clearly on the heaviest types of work, locomotive engine connecting rods and coupling rods can be milled in pairs at a high speed with powerful machines of the planer type.

The cutters are made and ground in the works and kept in duplicate in the tool room. On the above type of machine cutters of 6 in. diameter by 30 in. long can be used on the heaviest class of work. Another class is the rotary planing machine, the saddle of which travels along the bed, the cutters are built up into large discs, and may be up to 10 ft. diameter, these will tool up large surfaces in a very short time. As an instance of this a machine part having two parallel faces, can be fixed securely on a base plate, and two of the above cutter discs set operating together, each disc having 75 cutters. An electric motor of 40 h.p. was geared to each head.

One of the most important factors in the advance of milling lies in the powers of the machine to operate on its own cutters, an instance of which is given in Fig. 170 by Reinecker.

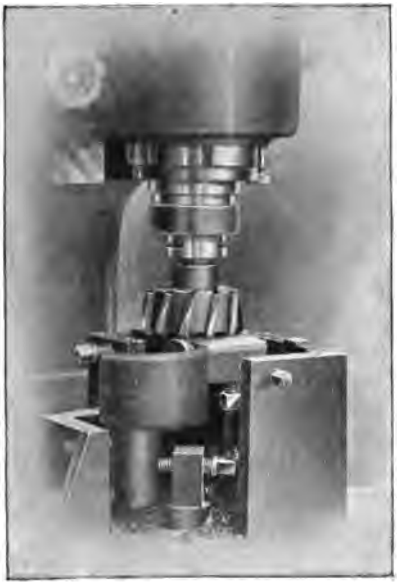


FIG. 171C.

In machines of the vertical class many surfaces can be tooled which would be difficult by other processes. Fig. 171 shows a steel clutch fork mounted on the table for circular milling. Levers, crossheads, and rod ends are examples of this class.

The further uses of the end mill on this machine are given in Figs. 171A and 171B in sinking a recess and milling a slot from the solid respectively. A cast iron bracket secured in a jig with a facing cutter showing inserted blades is given in Fig. 171C. In such work the milling fixture or holding jig shows to advantage; this particular example takes a few minutes to set up, whilst to do the same piece by ordinary methods the chucking proves to be a more expensive operation than the actual time in machining. The examples are from the works of Alfred Herbert, Ltd.

GANG MILLING

A number of milling machine vices held in a special jig are shown in Fig. 172, the work being secured on a plain horizontal milling machine. The sides of the vices have been previously milled parallel at another operation. Referring to the illustration, it will be seen that the cutter mandrel is supported at its outer end by means of a stout bearing, which is solid to the brace and arm respectively, the whole being bolted to the vertical standard which is actually secured at its base to the transverse slide. In addition to this there is a roller steady in the middle; this combination gives very satisfactory results, and keeps the cutters from vibration. These machines are by A. Herbert, Coventry.

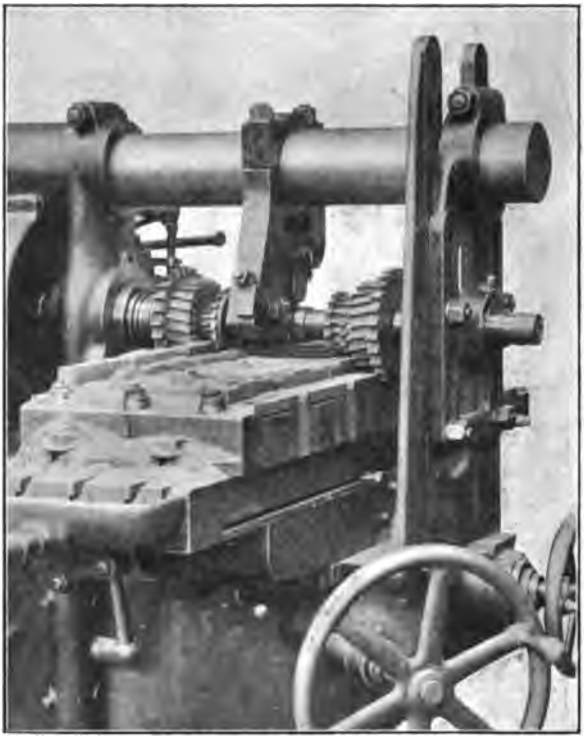


FIG. 172.—Gang milling machine vice.

In this example there are eight cutters in the gang at work, and at least four machine vices are under operation. One essential in this process is to group the individual parts in proper alignment so that each cutter has its share of metal to cut clean.

A gang of milling cutters, milling a number of toggle levers for the chucks of turret lathes, are shown in Fig. 173. Three inserted cutters are in use. On each cutter the teeth are adjustable endwise, so as to compensate for wear, and to ensure the milling of a constant width of slot. This is a very desirable feature, and acts equally with the expansion cutters which are fitted with a washer between the "plates," *i.e.* between the smooth, internal faces of the cutters, the thickness of the washer increasing proportionately with the decrease of the cutter by use and regrinding.

An interlocking plate, such as is used on railway signal work, is given in Fig. 174. In this example eighteen cutters are in use at one time. The cutters for milling between the lugs have teeth which overlap, and can be adjusted apart so as to compensate for wear.

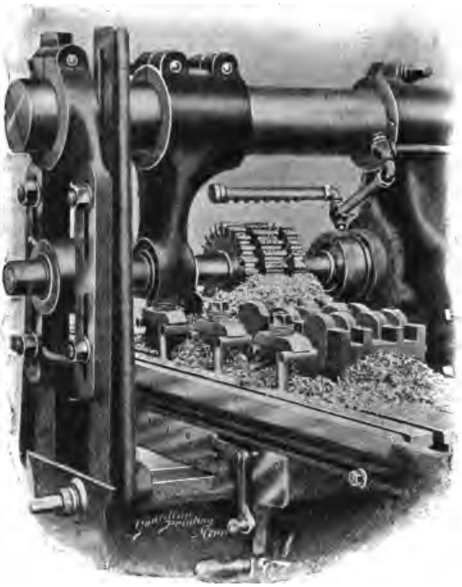


FIG. 173.

Referring to Fig. 172, an adjustable type of stay is fixed on the overhanging arm; these stays carry rollers which give direct support to the cutter mandrel; they can be adapted to any size of mandrel or, when not required, they may be swivelled out of use.

SPECIAL FORM OF MILLING JIG

In Fig. 175, a jig is shown of the tumbler type for tooling two similarly grooved ends, both at an equal angle, in a small but delicate bracket marked E.

The milling cutter, M, has teeth cut in the buttress form for tooling out the grooves. This is for locating at precisely equal distances a number (10) of teeth or combs between which the pivoted droppers may rise and fall. Referring to Fig. 175B, it will be seen that these parts, when assembled, control the movement of other mechanism, proving that accuracy in the holding and cutting the teeth in the frame E is most important.

The tumbler jig, Figs. 175, 175A, shows the bracket E, under the control in the first place of the locating pin or pivot C, this being the central point between the ends of the bracket or frame which has to be milled.

The housing pin thus placed leaves the central part of the jig and work free to swing; then P, which is a long pin, is first passed through the bearings at A, while one end of E is milled, P is then withdrawn,

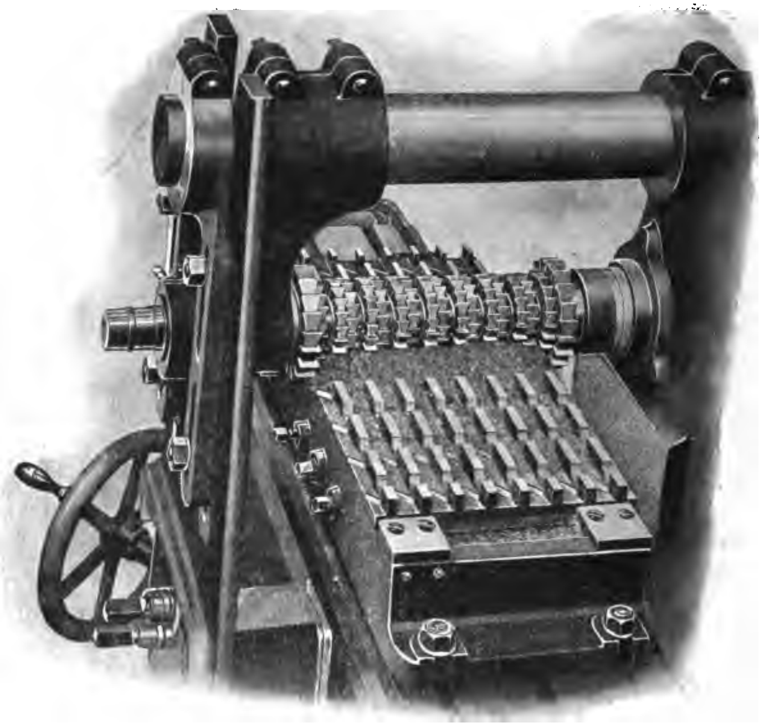


FIG. 174.

and the jig (Fig. 175) swings free again until the opposite end comes to the top, and the locating pin is passed into the upper bearing marked E (Fig. 175A).

This compact and accurately fitted milling jig serves to show what may be done by the aid of a special fixture. With its use hundreds of similar parts may be produced true to gauge, and although of an extremely delicate section yet without distortion. The inserting, locating, and tooling operations are carried out without trouble when the distance from the centre of C to the cutter has been carefully set.

On the other hand, to attempt such a piece of work without such

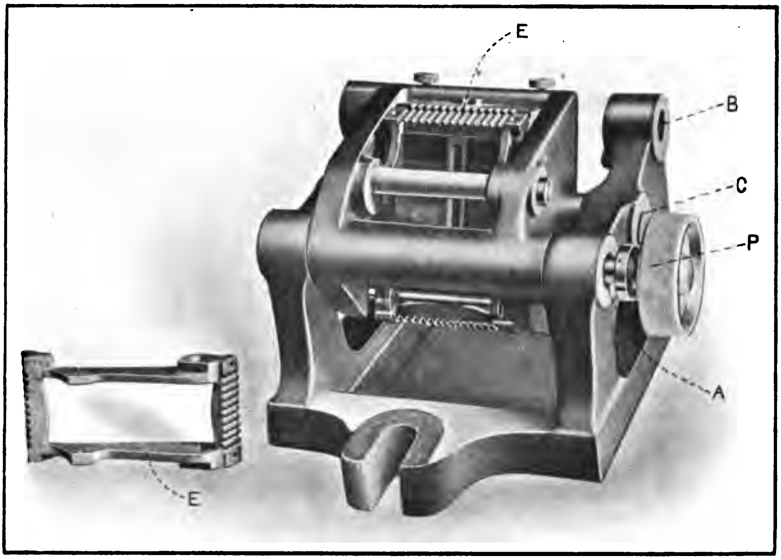


FIG. 175.—Tumbler jig for milling delicate frame, E.

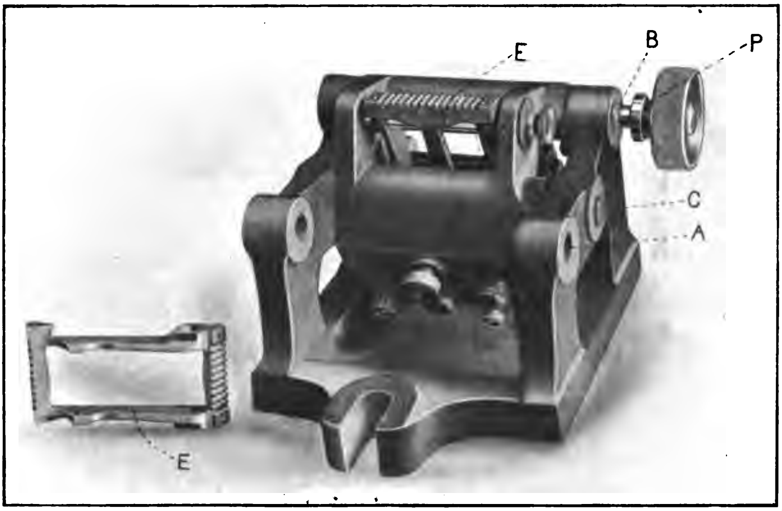


FIG. 175A.—Tumbler jig for milling delicate work.

an appliance would entail most careful setting out, since ordinary holding or securing appliances would be too bulky to use, while the risk of tooling the ends without fracture would be great indeed.

CUTTING SPEED FOR MILLING CUTTERS

"When it is taken into consideration that the right cutting speed for particular work is dependent upon the material that is to be machined, the cutter pitch, the cutting angle, also upon the feed, depth, and breadth of chip, etc., and not least upon the stability and good condition of the machine, it must be admitted that, with the co-operation of so many factors, a perfectly general determination of the cutting speeds presents certain difficulties. First of all, attention must be called to the inadequately distinguished cutting speeds for carbon steel, and high-speed steel cutters.

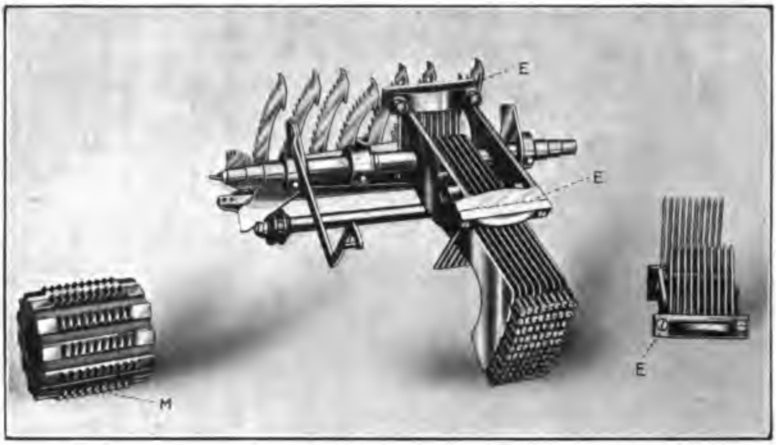


FIG. 175B.—Work assembled in frame, E, and milling cutter, M.

"As already mentioned, there is for every cutting tool a certain velocity which, due regard being paid to the influencing factors, can be designated as the most favourable. This best speed will give the highest efficiency for the least expenditure of power. With lathe and planing tools, drills, etc., this best cutting speed, however, often lies so high that its employment for carbon-steel tools produces much heating, and results in an unpermissible wear of the cutting edges. We are, therefore, compelled to diminish the speed for carbon-steel tools, while high-speed tools permit greater velocities at which they may be employed to advantage. Different cutting speeds are, therefore, appropriate for carbon and high-speed steel lathe and planer, tools, drills, etc. It is otherwise with milling cutters. For these the best cutter speed does not lie so high as to be unavailable with carbon-steel cutters. Moreover, the heating of milling cutter edges is less than that of the edges of lathe and similar tools, because the working period of the individual teeth is relatively short, and between each cut they have time to cool off in the air as the cutter turns round.

" Experiments were undertaken upon a horizontal high duty milling machine, in which was a block of medium, hard cast iron, 130 mm. wide (5·07 in.). There was used a cutter of high-speed steel, 90 mm. (3·51 in.) in diameter, with 18 teeth to break the chips. These helical teeth had an angle of inclination of 12°, a cutting angle of 5°, and were so formed as to break the chips. The feed in every experiment was 508 mm. (19·81 in.) per minute, the chips removed per minute, therefore, were 264·15 cubic centimetres (16·1 cubic in.). The operation was thus a roughing one, such as is only possible on modern machines of extraordinary performance. The results of the experiments are set forth in Table I. This experiment showed that with a constant feed and depth of cut and variable cutting velocity, there is an important increase in the power consumed. When the two lowest cutting speeds, 6 and 7·3 were used, there was easily perceptible a lessening of smoothness in the piece of work. If the above test be applicable only to the case described, it permits an inference that the often employed cutting speeds of 20 to 25 metres (65 to 82 ft.) per minute for roughing cast iron are very little warranted, and that they only increase the power consumed. Too low cutting speeds are, of course, to be avoided also, since they prejudice the smoothness of the work.

" Table II. shows cutting speeds for machining various metals with milling cutters. The values therein set forth have been arrived at in practical working experiments, and are applicable to powerful milling machines and cutters, with normal teeth."—" Mechanical Engineer," Vol. xxv. p. 731.

TABLE I.—Cutting Speed corresponding to Spindle Revolutions and Pounds of Chips removed per Hour

Cutting speed, feet per minute . . .	19·7	23·9	29·5	37·7	45·9	57·4	70·5	86·9	106·6
Cutter revolutions per minute . . .	21	26	33	41	50	62	76	94	115
Horse-power, input to machines . .	6·66	6·85	7	7·4	7·84	8·13	8·73	9·42	10·3
Chips removed per horse-power per hour, pounds . .	34	33·7	32·8	31·3	29·5	28·6	26·8	25	23

TABLE II.—CUTTING SPEEDS FOR VARIOUS METALS

Material.	Cutting speed in feet per minute.	
	Roughing work. About 0·156 in. cut.	Finishing work. About 0·02 in. cut.
Cast iron :		
Soft	39-49	59-65
Medium hard	29-39	49-59
Hard	20-26	39-49
Cast steel :		
Soft	39-49	59-65
Medium hard	33-39	49-59
Hard	20-26	39-49
Hard cast steel :		
Soft	59-65	79-85
Medium hard	49-59	65-79
Hard	39-49	59-65
Machinery steel :		
58,000 lbs. per square inch	53-65	98-105
72,500 lbs. per square inch	46-59	82-98
87,000 lbs. per square inch	39-59	65-82
101,500 lbs. per square inch	33-39	53-65
116,000 lbs. per square inch	26-33	46-53
Tool steel :		
Soft	26-33	46-59
Medium hard	20-26	33-50
Hard	13-20	26-33
Bronze :		
Soft	92-98	131-148
Medium hard	82-92	125-131
Hard	72-82	98-125

RELIEVING THE CUTTING EDGES OF HOBS, TAPS, AND MILLING CUTTERS

Originally the clearance or relief to each cutting edge of hobs, taps, reamers, and milling cutters was left to the tool fitter to form by hand chipping and filing. The workmen were experts with the tools, but the process was slow and uncertain, as was the life of the cutters when hardened and finished. Top wages were paid for this skilled and tedious work, which often included the use of the cutters, especially mills.

The clearance was not enough, because the pitch was too fine and the cutters would clog and fracture, sometimes when only few pieces of work had been tooled. This of course meant annealing, refiling the cutting edges, and re-hardening and tempering. Repeating the process several times, the cutters would deteriorate, either showing cracks or would change in form, and sometimes would not retain a cutting edge.

It is therefore easy to see that this costly method put a check on the advance of milling as a system. It was not before Messrs. Brown

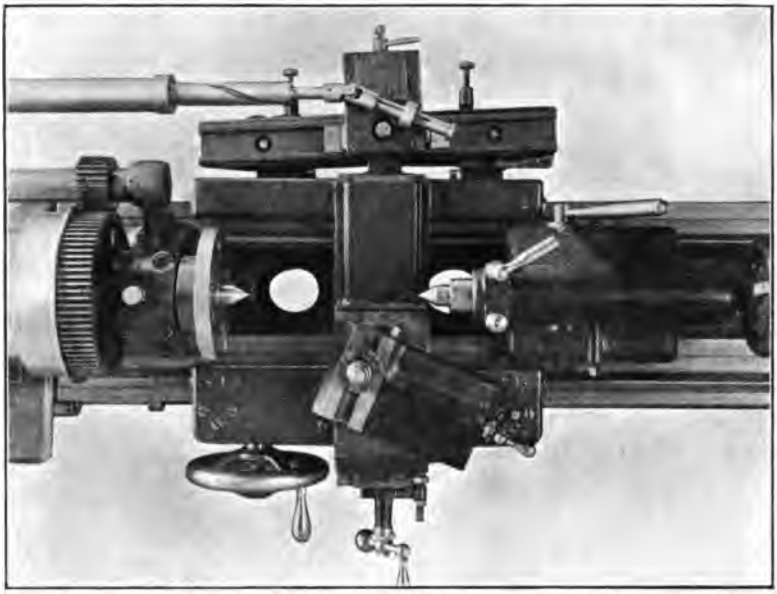
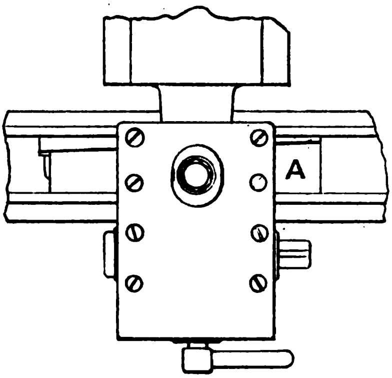


FIG. 176.—Plain view of relieving attachment.



and Sharpe introduced their relieved milling cutter that the system of milling was put on a permanent basis.

An arrangement is given in Fig. 176 of an attachment to a lathe by Messrs. Pratt and Whitney Co. The taper bar slide or frame is shown in drawing, 176A. A is fitted to the bar B and carries the cam shaft H. The roller slide C is clamped to the cross slide D by means of the bolt E, the cap F holding the roller slide in

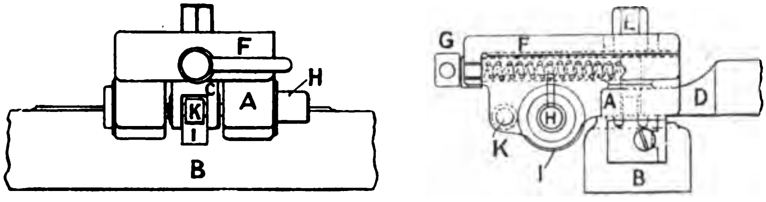


FIG. 176A.—Relieving attachment.

position and carrying the binder screw G. When the cam shaft has to be removed, roller K and slide C may be withdrawn, and clamped to cap F by binder screw G, the relieving attachment then becoming one rigid member, in which condition it can be used in place of the regular taper bar slide; by unscrewing bolt E the attachment can be removed entirely.

When relieving a tap or hob in which the flutes are cut parallel with the axis a straight grooved cam-driving shaft is used so as to cause the cam to force the cross-slide forward once for every flute or tooth. Fig. 177 shows a large hob in process of being relieved. On account of the size of the teeth it was found advantageous to relieve the sides, top, and bottom in separate operations. By setting the compound rest to the proper angles this was done with ordinary side and square-nose tools, a side tool being shown in the illustration.

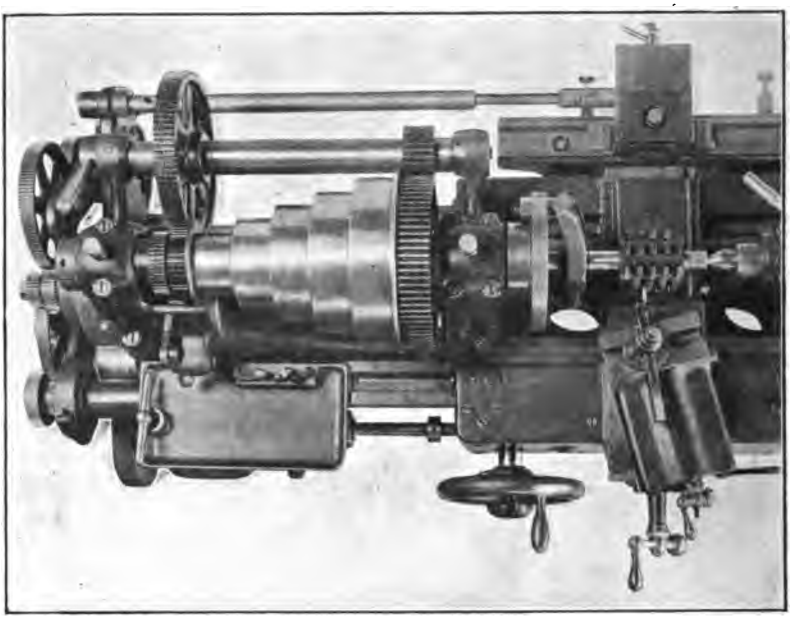


FIG. 177.—Relieving a hob.

RELIEVING ATTACHMENT

Fig. 178 shows a tap for a lead screw nut having its lead corrected by grinding after hardening, to ensure good contact of screw and nut.

Figs. 179 and 180 show the lathe arranged for relieving and grinding a hob fluted at right angles with the thread. In this case it is necessary to use a cam-driving shaft grooved spirally to correspond with the head

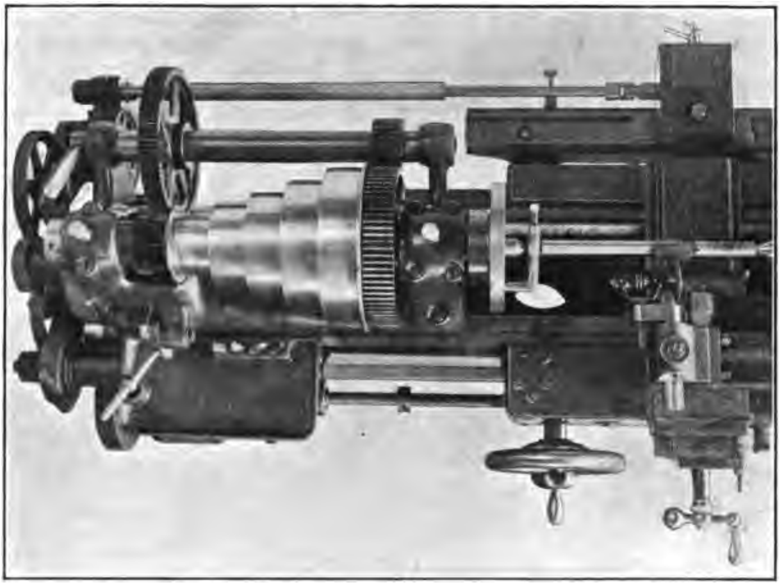


FIG. 178.—Correcting the "lead" of a tap.

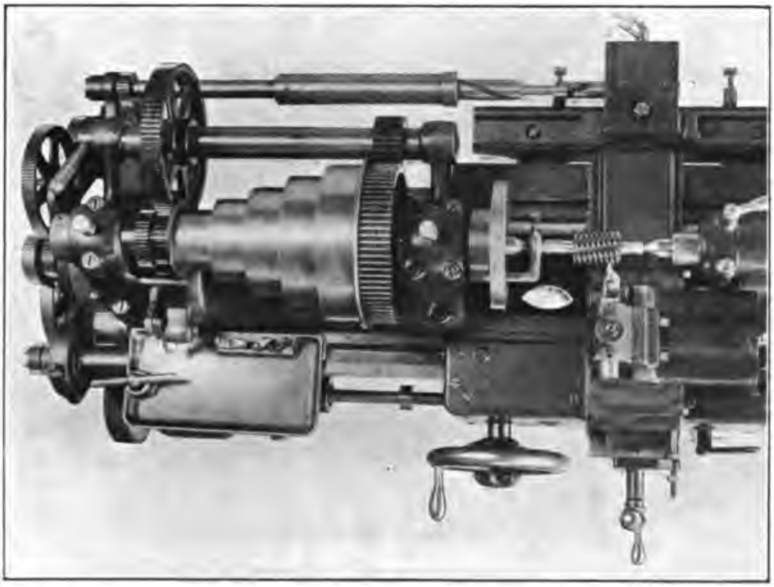


FIG. 179.—Relieving a hob, fluted at right angles to the thread.

of flutes as shown, or a straight grooved shaft geared to compensate for the spiral may be used.

By using cams of a different number of rises geared according to the index plate the same spiral groove will do for a number of different leads of flutes.

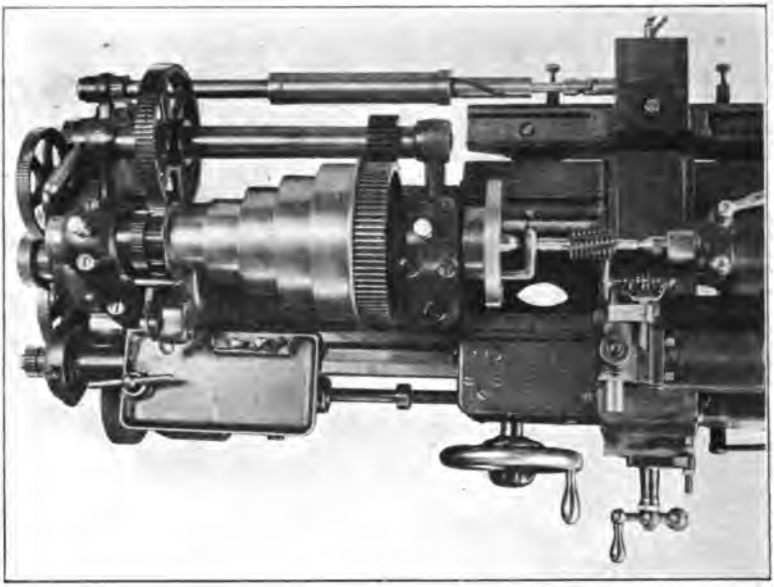


FIG. 180.—Grinding a hob, fluted at right angles to the thread.

For example, let A = Lead of flutes in work,
B = Number of flutes in work,
C = Number of rises in cam,
X = Lead of groove in shaft.

Then $$\frac{AC}{B} = X.$$

If A = one turn in 60 inches
B = 8
C = 2.

Then $$X = \frac{60 \times 2}{8} = 15 \text{ inches.}$$

Substituting single, triple, and quadruple rise cam it will be seen that the

Single rise cam will require one turn in 7½ in.
Triple ,, ,, ,, ,, 22 in.
Quadruple ,, ,, ,, ,, 30 in.

Furthermore, if a shaft grooved exactly to correspond with theoretically correct lead of flute in the work, should not be at hand, it has proved practicable to select a shaft somewhat long in lead of groove, and flute the work to suit. By reversing the cam and running the shaft in the opposite direction the same shaft can be used for right- and left-hand spirals.

ADVANCED WORK. SETTING OUT AND TESTING A TEMPLET

An example of testing the accuracy of a marked-out templet is given in Fig. 181. The height gauge by Brown and Sharpe serves a

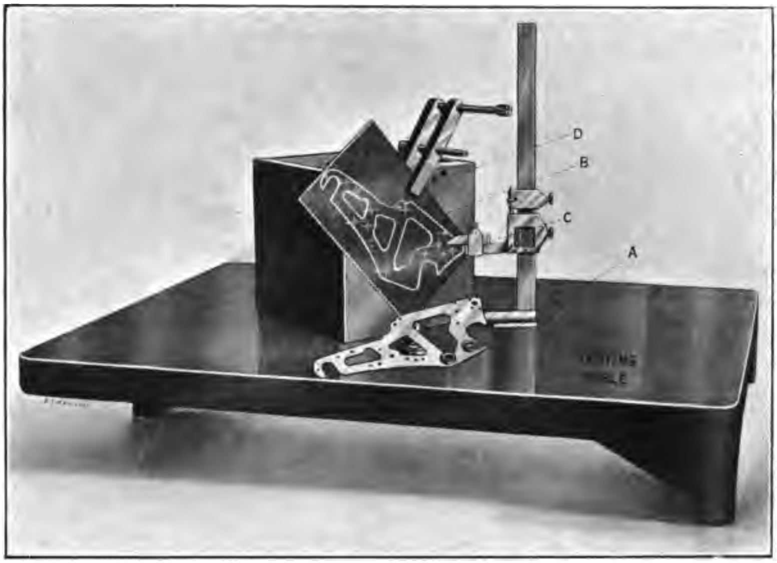


FIG. 181.—Advanced setting out testing with height gauge.

useful purpose in obtaining and verifying the relative positions of important centres. This instrument, which is finely graduated and provided with a vernier, may be read to one ten-thousandth of an inch. The movable jaw C is sharpened to a knife edge, so that very fine lines may be traced. The object A on the table is a sample of precise work produced by the aid of a jig. Considering the area covered, and that there are 23 holes pierced in the correct positions on an example so fragile, the value of a carefully constructed drilling jig should be appreciated where great numbers of similar pieces are to be made. Reference may be made to the tool-maker's clamp, shown holding the example to the true surface of the block D. This is a useful appliance, at a marking-off table for small and medium sized work, also at the bench for holding pieces temporarily together, such as punch and die work, and in die sinking and other similar parts. The testing table is in reality a highly true surface plate, upon the face of which the various pieces may stand erect or slide evenly. The block D is a hollow casting scraped to a surface on each face. Small parts, having one or more faces tooled, but which require still further operations, may be pressed against one side of the block and marked, otherwise the same parts would need to be packed up, or held against the edge of a true square, to obtain a truly vertical setting.

END MEASURING INSTRUMENTS

An instrument for testing the length of machined rods, is given in Fig. 182. The rod or shaft S is placed in its proper notch in the gauging frame, which is provided with a taper slot T. Accurately fitting the slot is a slide N, which has a transverse mark along its length. There are graduations on the margin of the frame, therefore if the shaft or rod is made to the correct length the indicator will point right, a longer or shorter rod will easily be noted on the scale. The taper is a very small amount per foot, so that the error locally will be detected, even when it is very minute.

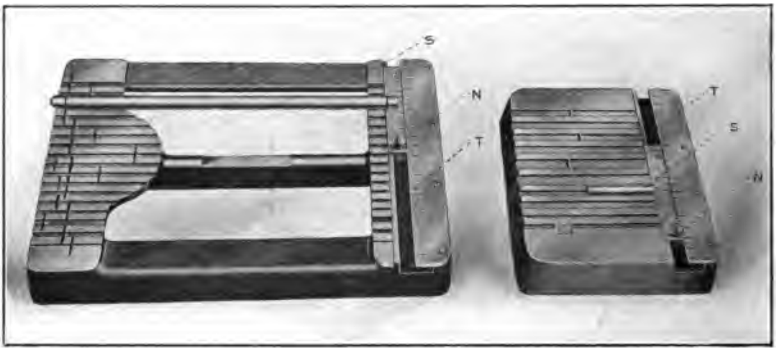


FIG. 182.—Gauging instrument testing length of rods.

ADVANCED EXAMPLES. GAUGING AND TESTING

A further example of testing a finished piece of work is given in Fig. 183. The part A is a detached piece of mechanism supported on Vee and parallel blocks B on the testing table. In this case the precise location of the parts is the object of the test. Minute adjustment can now be made and verified by the height gauge knife at C. The vernier giving the relative positions of the parts to a high degree of accuracy, all, however, being measured from the true surface of the plate.

It may not be without interest to know that there are over 2000 parts in the above machine, and when fully assembled there is no alteration or subsequent correction needed. The finished machine is used as an Adding and Registering machine, *i.e.* the cash sums are added and total stated. The system in manufacture is of the interchangeable plan. As each operative receives his batch of work he has a perfect set of tools handed from the tool room. On the completion of the work, the tools are also returned, inspected, and, if necessary, corrected, and re-ground to gauge.

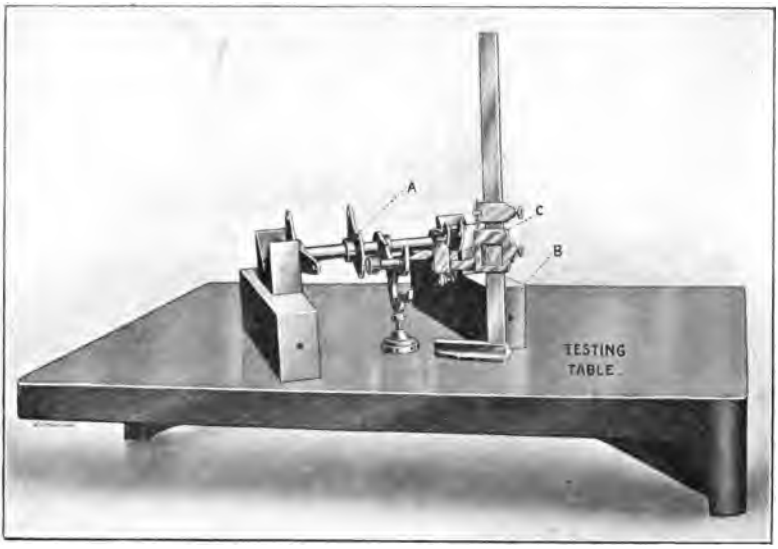


FIG. 183.—Testing the truth of a finished mechanism.

DELICATE WORK IN DRILLING JIG

In Fig. 184 a special jig is shown for holding the very slender cast-iron side frame or standard seen in Fig. 185. In this example the delicate construction of the casting renders the task of evenly, yet securely, holding it under the drilling machine a difficult one. With the aid of the above jig, however, there is no difficulty of holding the piece, nor of locating, drilling, and reaming the various spindle holes. The jig, which is properly fitted with hardened and ground steel bushings, and which is further provided with suitable seatings upon which the side frame must evenly rest; and the jig cover which forms a counter part, is also similarly provided with locating holes, so that when the casting to be drilled and reamed is located in the jig, it may be instantly secured by the cover and the wing nuts shown.

This jig is so constructed that it may be inverted for use on the opposite side. Therefore, the one jig answers for two frames, *i.e.* a pair right- and left-hand frames may be accommodated. One of the successful points of this arrangement is the perfect coincidence of the seatings in the jig with those on the work. So carefully is this important part done that in using an "end mill" on the seatings on the side frame a $\frac{2}{1000}$ of an inch is left for a second operation, that is, the work is removed and re-set for a final $\frac{2}{1000}$ cut. This of course liberates all springing, as the second securing is much lighter than the first.

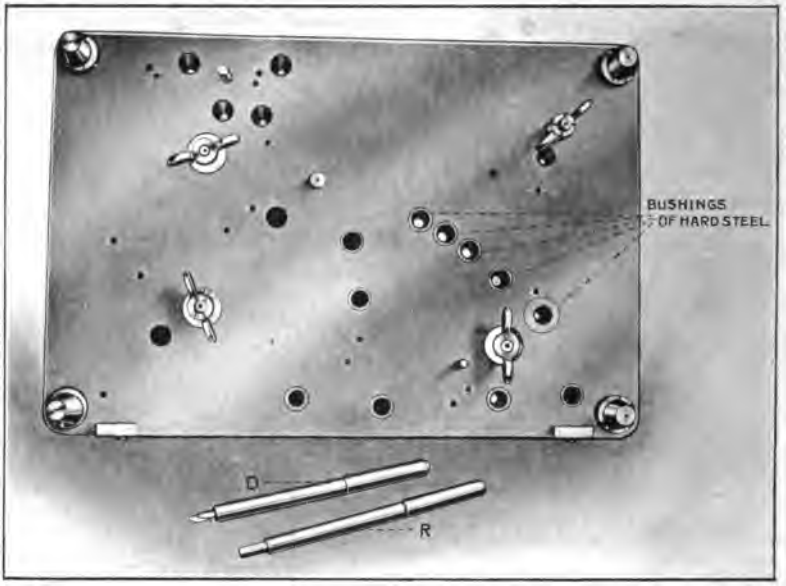


FIG. 184.—Jig cover and tools.

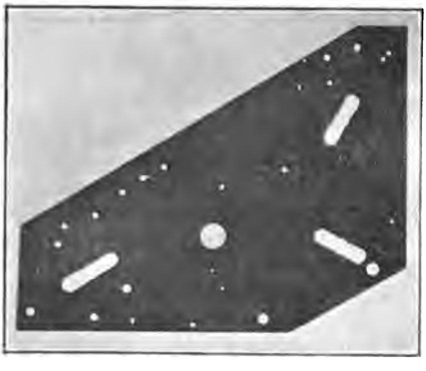


FIG. 184A.—Jig cover for side frame.

A unique and very satisfactory arrangement is shown at the base of Fig. 184. The drill and the reamer shanks are all made perfectly true by grinding, also they are all of a like diameter. Therefore, it matters not what size of hole has to be drilled, the shanks being alike in their fitment, will slide in any one of the several bushings as desired. In

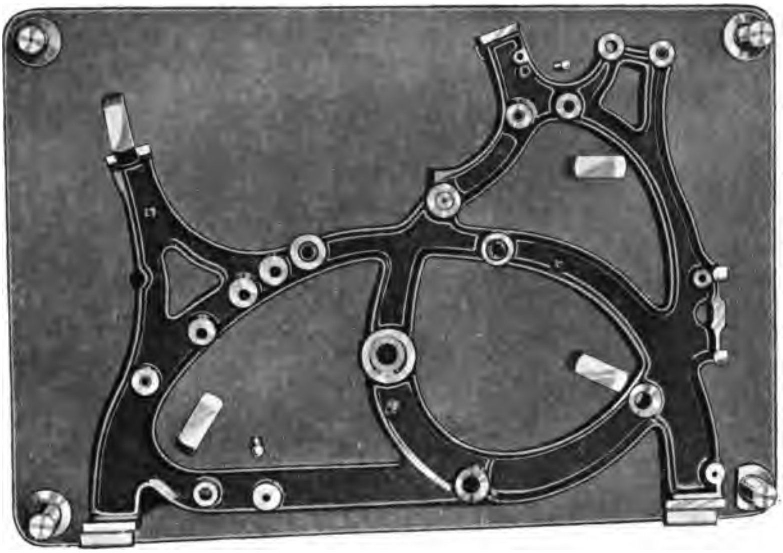


FIG. 185.—Side frame, adding and registering machine.

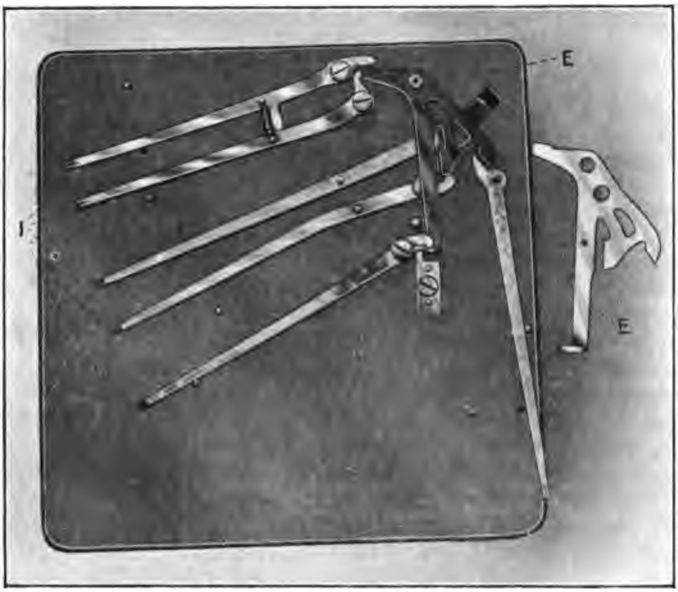


FIG. 186.—Sensitive gauging instrument.

the case in point thousands of holes have been drilled and reamed, but there is still no appreciable wear in the bushings or on the tool shanks. Contrasting the usual method with the above, that of passing drills and reamers directly rubbing on the hard walls of the bushings, it must be obvious that both wear; moreover, the above method reduces vibration to a minimum. Another important test is that of gauging the example E in Fig. 186. The special indicator levers, which are pivoted near to the object E, are all made with sensitive fingers which terminate on an indicated board or table about I. Any errors in milling at the ends of E are shown in a multiplied form by the readings on the graduations at I. In this way the actual pieces when gauged and passed are within $\frac{2}{1000}$ of an inch of error.

The peculiar bends in the above object are such as to need a special form of jig, so that the act of milling the parts referred to will neither cause deflection nor jar on the thin surfaces while under cut.

Notes on Gear Wheels

It is claimed that machine-moulded gear wheels are much superior to hand-moulded gears. In the latter case a full pattern must be employed, and, consequently, the diameter at the roots of the teeth must be unequal, owing to the rapping necessary to withdraw the pattern out of the sand. There is also the draft given to the pattern to assist it. A further defect is that in removing the pattern some parts of the teeth of the mould may get broken off, which would necessitate the moulder to patch up the defects. It is, therefore, seldom that a perfectly uniform cast-gear can be obtained, so that extreme care must be exercised in setting these castings truly in the lathe. Obviously the tops of the teeth are not always a true indication of the truth in running of the flanks and roots of the wheel teeth. In machine-moulded gears the above troubles are eliminated. There is just needed one block, having the form of a single tooth space for making the teeth moulds, around the full diameter. The teeth are, therefore, true to pattern, and being parallel no draft is necessary. After casting the facing sand falls away or may be brushed off, leaving the casting clean and having a smooth skin. Made in the above manner the gears compare with the best-cut wheels for shape, and although not so perfectly smooth as the latter in running, yet they have a much stronger tooth, since the carbon (scale) on the exterior is not disturbed.

On the other hand, the gears cut from turned blanks are much softer, but as each tooth takes a uniformly distributed share of the load or pressure there is little fear of these gears breaking. When, however, the wheels are subjected to sudden shock the teeth may be very much strengthened by having a flange cast on each side. It is almost impossible to fracture the teeth of such gears. They are usually known as shrouded wheels and pinions. In some cases the wheels are shrouded on one side only, so that the teeth may be clear as in a sliding clutch arrangement. For very heavy transmission, as in crane work, wheels of this type are used or they may be shrouded to about the pitch circle. This is frequently seen in the double-helical wheels.

NOTES ON GEAR CUTTING

The circular pitch is the distance from the centre of one tooth to the centre of the next tooth, measured along the pitch circle.

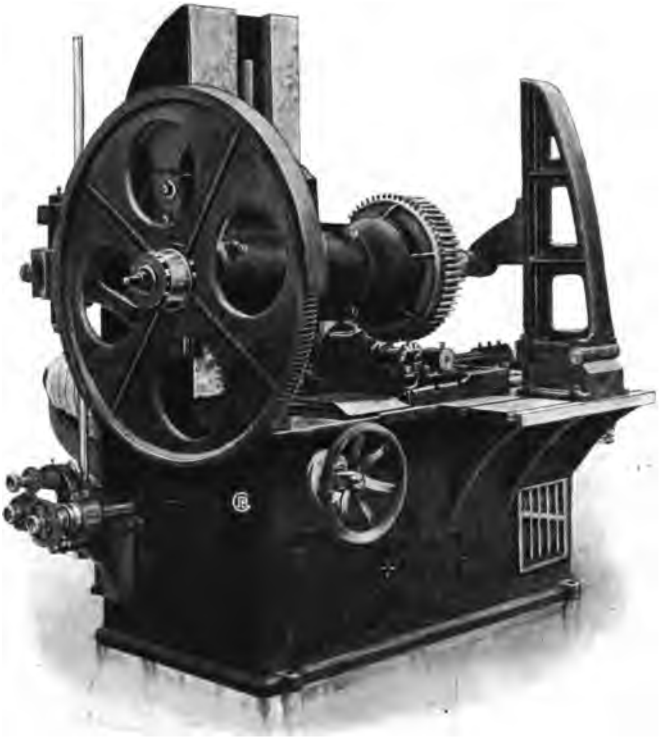


FIG. 187.—Reinecker's automatic spur gear cutting machine.

If the distance from the centre of one tooth to the centre of the next tooth = $\frac{1}{2}$ in. the gear is $\frac{1}{2}$ in. circular pitch.

The circular pitch and number of teeth in a wheel being given, the diameter of the wheel and size of the tooth parts are as follows :—

Dividing by 3·1416 is the same as multiplying by $\frac{1}{3\cdot1416}$. Now $\frac{1}{3\cdot1416} = 0\cdot3183$; hence multiply the circumference of a circle by 0·3183, and the product will be the diameter of the circle. Multiply the circular pitch by 0·3183, and the product will be the same part of the diameter of pitch circle that the circular pitch is of the circumference of pitch circle. This part or modulus is called a diameter pitch. There are as many diameter pitches contained in the diameter of pitch circle as there are teeth in the wheel. Generally the addendum or total depth of tooth is equal to one diameter pitch. Hence we can designate this modulus or diameter pitch by the same letter as we do the addendum, that is,

Let S = a diameter pitch.

$0{\cdot}3183\ P' = S$, or circular pitch multiplied by $0{\cdot}3183 = S$ or a diameter pitch.

$Ns = D'$, or number of teeth in a wheel multiplied by a diameter pitch, equals the diameter of the pitch circle.

$(N + 2)S = D$, or add 2 to the number of teeth, multiply the sum by S and product will be the whole diameter.

$\frac{t}{10} = f$, or one-tenth of thickness of tooth at pitch line = amount added to the bottom of space for clearance.

It is generally preferred to make $f =$ to $\frac{1}{16}$ of the working depth of the teeth, or $0{\cdot}0625D''$. One-tenth of the thickness of tooth at pitch line is more than one-sixteenth of the working depth, being $0{\cdot}07854D''$.—Brown and Sharpe's "Gearing."

Gears and Gear Cutting

Example.—Sizes of gear blanks and tooth plain parts for a gear of 30 teeth $1\frac{1}{2}$ in. circular pitch.

$P' = 1{\cdot}5$ in.; then $t = 0{\cdot}75$, or thickness of tooth $= \frac{3}{4}$ in.

$S = 1{\cdot}5$ in. $\times\ 0{\cdot}3183 = 0{\cdot}4775$ in. = a diameter pitch.

$D' = 30 \times 0{\cdot}4775 = 14{\cdot}325$ ins. = diameter of pitch circle.

$D = (30 + 2) \times 0{\cdot}4775 = 15{\cdot}280$ = diameter of addendum circle.

$f = \frac{1}{10}$ of $0{\cdot}75 = 0{\cdot}075$ = clearance at bottom of space.

$D' = 2 \times 0{\cdot}4775 = 0{\cdot}9549$ = working depth of teeth.

$D'' + f = 2 \times 0{\cdot}4775 + 0{\cdot}075 = 1{\cdot}0299$ = whole depth of space.

$S + f = 0{\cdot}4775 + 0{\cdot}075 = 0{\cdot}5525$ = depth of space inside of pitch line.

$D'' = 2S$ or the working depth of teeth is equal to diameter pitches.

The distance between the centres of two gears is evidently equal to the radius of pitch circle of one wheel added to that of the other. The radius of pitch circle is equal to S multiplied by half the number of teeth in the wheel.

Hence, if we know the number of teeth in two wheels in mesh, and the circular pitch, to obtain the distance between the centres we first find S, then multiply S by one half the sum of number of teeth in both wheels and the product will be distance between centres.

Example.—What is the distance between the centres of two wheels 35 and 60 teeth, $1\frac{1}{4}$ in. circular pitch? We first find S to be $1\frac{1}{4}$ in. $\times\ 0{\cdot}3183 = 0{\cdot}3979$ in. Multiplying by 47·5 (one half the sum of 35 and

60 teeth) we obtain 18·899 in. as the distance between the centres.—Brown and Sharpe's "Gearing."

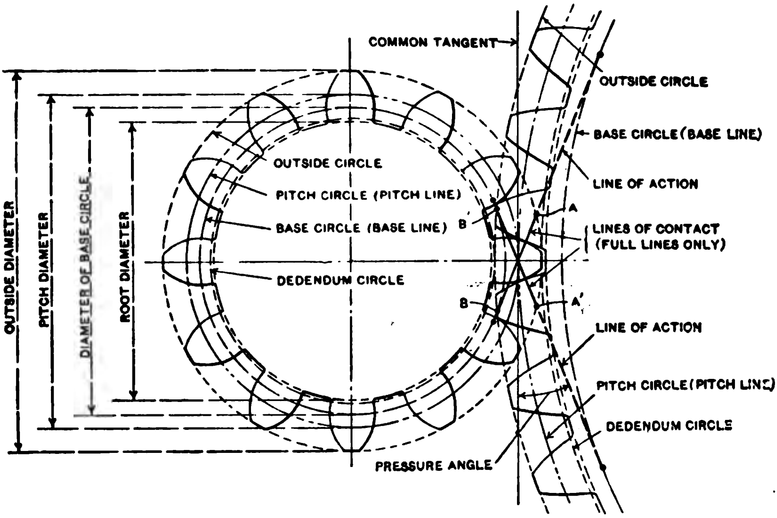


FIG. 188.—Diagram showing definitions relating to spur gears.

"INVOLUTE CUT GEARING"

"The first accurate gearing in general use was the cycloidal form. This is a system whereby the odontoids were produced by the rolling of a circle on the pitch line, a point on this rolling circle generating the tooth curve. By rolling on the outside of the circle the face odontoids were produced (termed epicycloids) and rolling on the inside the flank curves or hypocycloids were produced, hence two curves of opposite directions formed the tooth side, these curves meeting at the pitch line. In consequence the system is sometimes referred to as the two curve system. When produced as a rack both curves are alike.

"The great defect in the cycloidal system is that the pitch circles must be always at exact centres, because the curves of the odontoids change at the pitch line. Failing this condition, all rolling action is entirely lost, and noise, friction and wear result.

"Another feature of cut gearing which should be entirely done away with is that of the circular pitches, being both clumsy and unsatisfactory."[1]

The standard at the present day and one which is quickly superseding the older system, is the involute tooth (Fig. 196) and the diametrical pitch. The circumference of a circle in terms of its diameter is 3·14159, etc., an incommensurable fraction; therefore, measuring an arc of circle, one of two inconveniences arise. Either the pitch must be an inconvenient fraction or else the pitch diameter, and consequently the centres for the gear, must have a definite number of teeth. Dealing with the diametrical pitch first, this is strictly speaking a ratio rather than a measurement, being the number of teeth in the gear divided by the pitch diameter of the gear. Thus a gear of 80 teeth 20 inches diameter is 4 or S pitch. The advantages are so apparent that it is quickly becoming universal. It may be defined as the number of teeth in one inch of the diameter.

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[1] "Involute Cut Gearing," S. H. Rowley.

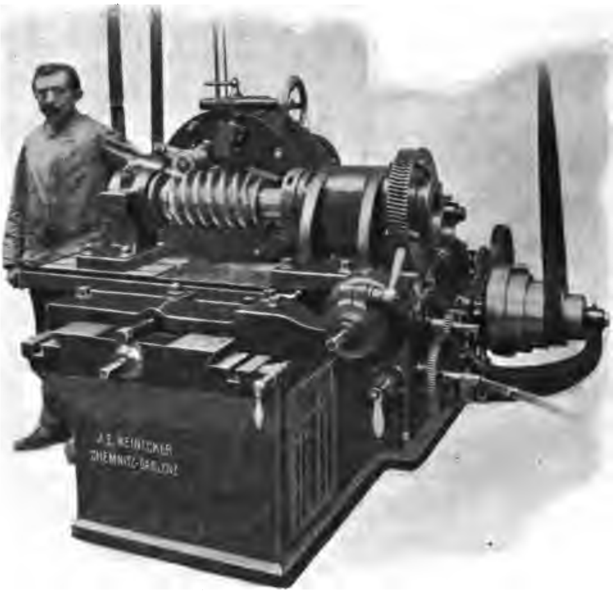


FIG. 189.—Cutting a large worm for hobbing cutter.

INVOLUTE GEAR CUTTING

Then, again, to obtain the blank diameter, two teeth are added and the result divided by the pitch. Taking the above example $\frac{80 + 2}{4} = 20\cdot5$ the blank diameter.

The system in vogue on the continent is the metric, all dimensions being in millimetres. The module being the addendum or the pitch diameter in millimetres divided by the number of teeth in the gear. In the evolution of the involute system $14\frac{1}{2}^\circ$ angle of pressure or obliquity was adopted as the basis, probably on account of its convenience in setting out, the sine of this angle being practically one-fourth. The length of tooth should be sufficient to give an arc of contact between two meshing teeth, at least equal to the pitch arc, with the smallest pinions, twelve being the minimum in practice. This enables one pair of teeth to keep in contact until the next ones are in position for taking up the load.

It naturally follows, therefore, that there is a fixed relation between the obliquity of the line of action and the length of tooth.

A length of tooth beyond that which is necessary to insure a continuity of action produces undue friction and wear, the best results being obtained when the arc is from 1¼ to 1½ times the pitch arc.

One of the most valuable features of the involute curve is that the centres of the two gears may be varied to such an extent that they only engage at the points, and will work together in perfect contact and constant velocity ratio, the lines of action and the pitch line moving with the curves resulting only in excessive backlash. The rule, however, only holds good where both gears are above a certain number of teeth.

In pinions the arc of action must not be reduced below the equivalent of the circular pitch, nor must the curve go beyond the limit line, or line of interference when the centres are closed in. The twelve-tooth pinion is the smallest that will have an arc of action as great as the pitch, but eleven and even ten teeth may be used, the error being practically negligible.

It is possible to design teeth on this system with as few as three teeth in the pinion. Such a pinion, however, would require a special wheel to gear with it, and would not form part of an interchangeable system.

Conditions which refer to spur gears apply equally to internal or annular gears, but what is tooth in the one becomes space in the other.

It is possible to make a pair of wheels of which the pinion has only two teeth less than the internal.

This is effected by omitting the face of the teeth of either gear, either by making the pinion tooth all dedendum and the wheel all addendum, or *vice versâ*.

In practice it is found desirable to make the pitch diameter of an internal gear somewhat larger than standard size, that is, assuming the wheel forms part of a train, say, with a central pinion and intermediates.

The motor-car industry has done much for the development of accurate cut gearing during recent years, excessively high speeds, great strength, and noiseless running being necessary. To obtain these results has called for the closest study of the action of the teeth, extreme accuracy in the cutting, and the elimination of undercut in pinions.

We are apt to regard the present tooth as a fixed law, but this is not the case, and there has within the past few years been introduced by the Fellows Gear Company, a system of gearing termed the Stub Tooth, which is growing more and more in favour, although it is as yet little known to general engineers, at least those outside the automobile industry.

It is now proposed to indicate the method of producing involute cut spur gear. The first system of accurate interchangeable cut gearing was made practicable by Messrs. Brown and Sharpe, of America, who introduced sets of relieved disc cutters which could be sharpened without altering their shape. There are eight cutters in the set.

A rack having teeth with straight sides at an angle of 29° forms the basis of the system, twelve teeth being taken as the smallest pinion. The teeth were based on the correct involute form, but when a pinion so made is rolled in a rack, it is found that to avoid interference the flanks of the teeth must be considerably undercut, producing a very weak tooth; further, it would have been impossible to cut them with a disc cutter. Interference is most apparent between racks and pinions, and is due to the path described by the point of the rack tooth, crossing the involute face of the pinion near the base line.

An important part of acting face of the pinion has, therefore, to be cut away to clear the rack, and consequently a loss of a large portion of the arc of action. It was, therefore, decided to make the flanks radial.

This necessitated a modification of the involute on the tops of the teeth faces of the wheels, resulting in a compromise, and from its introduction about the year 1874, the system has been modified from time to time.

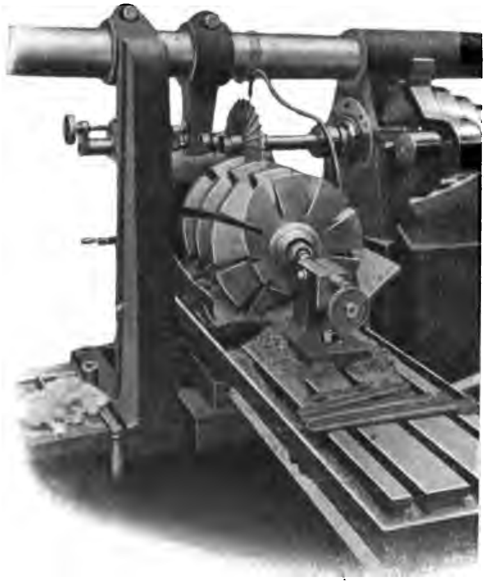


FIG. 190.—Reinecker Miller cutting spaces in large hobbing cutter.

The result at the present day is an evolution by a trimming process from errors which have become apparent from time to time in the past, and is to some extent a trade secret. For moderate speeds, excellent results are obtained, and to further increase the efficiency it is possible to get ten cutters to the set, or even specific cutters for specific numbers of teeth.

Another method of producing spur gears is to plane the teeth, using an enlarged former as a copy, as in the Gleason type of machine.

SPUR GEAR GENERATING

The most modern method, however, of producing spur gears is to generate the teeth, an entirely different process from the formed disc cutter, where one tooth is finished before the next is begun. The spaces cut in the blank will have the exact contour of the cutter. The basis of the involute system, as before stated, is the rack, and on this fact is built up the hobbing, and similar generating methods, which have come into such general use during the last few years.

The principle of hobbing gears consists of the rack tooth in the form of a spiral wound round a cylinder, practically forming a thread, with spaces cut across it at right angles to the spiral and parting the thread into so many teeth, which are backed off and result in a hob. With this hob spur gears of any number of teeth can be generated from a twelve-tooth pinion or less, to reproducing a similar rack. In the older method of gear cutting the teeth are an approximation only, but by generating, the correct form of tooth is produced for each individual gear.

The hob is fed down through the blank, the blank and the cutter being geared together by change wheels, so that they revolve at the correct ratio between the number of teeth to be cut and the teeth in the hob. In other words the pitch line of the hob teeth and the pitch line of the blank travel at the same fixed ratio, hence the hob makes as many turns per revolution of the blank as there are teeth in the gear to be cut. The hob teeth literally cut a way for themselves through the blank.

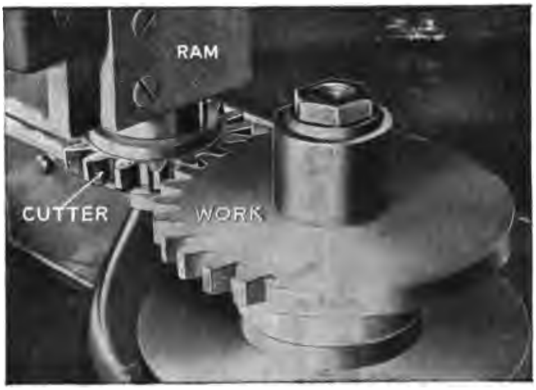


FIG. 191.—A Fellows gear shaper cutter at work forming the teeth of a spur gear.

The hob must be tilted with its axis to the angle of the spiral of the thread, so that the tooth of the hob is parallel to the blank at the instant of cutting.

The other essential in setting is that some one tooth of the hob must exactly coincide with the centre line of the blank mandrel, this tooth finishes the bottom of the teeth in the gear. The teeth are generated simultaneously.

The system in theory is pretty well perfect, but in practice it has certain objections. Consider the action of the hob when in operation.

As before stated, the hob is geared in ratio to the blank, but the hob consists of a number of cutting points, with intervening spaces (Fig. 190), hence the cutting action is intermittent, while the blank is moving at a constant speed. Therefore a portion of the metal slips past the tooth, and if the teeth of a hobbed gear be very closely examined on their faces, there will be found a series of minute flats. If we could conceive of the hob as a continuous spiral without any teeth, but still capable of acting as a cutter, the resulting gear would then be perfect in the same degree that the hob was perfect. It is therefore desirable to get as large a number of cutting teeth as practicable in the hob. It was stated that the hob was tilted over, or set at an angle with the blank so that the cutting teeth were parallel with the blank.

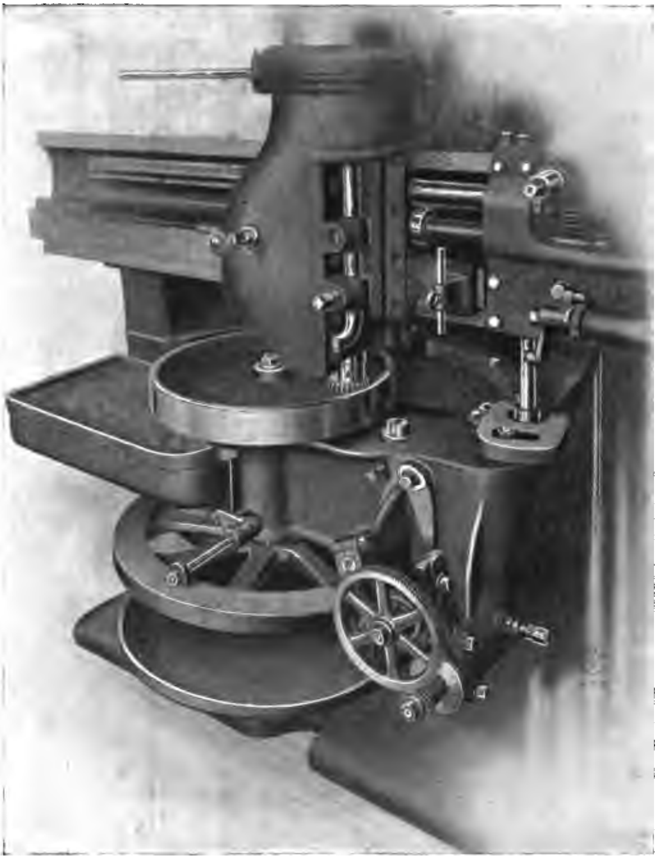


FIG. 192.—Cutting an internal gear wheel.

The cutting faces of the teeth, however, are a spiral; it is therefore an impossibility to set the teeth absolutely square. The tooth of the hob being actually at a slight angle, cuts a space slightly less in width than itself, the effect on the gear being to leave the points of the teeth oversize. Hobbed gears will be found to bear heavy on the points, therefore, when produced from a straight-sided hob. Another objection is the undercut that is produced on all wheels with less than 30 teeth, *i.e.* making a weak tooth. The flexibility of the system, however, enables results to be obtained which, perhaps, will be more or less a revelation to many, and the following remarks are worthy of special note.

If the blank be made a little larger diameter than standard and the tooth cut to standard depth, the base circle from which the involutes are produced is not in any way altered, but we get teeth strong in the roots with short flanks and long addenda. Pinions cut by this method will gear perfectly with any wheel or rack cut to standard sizes, and in many cases the teeth will be 50 per cent. stronger. It necessitates, however, the centres being set further apart.

There is another feature of the generating process to which attention should be drawn. With the teeth being all cut simultaneously there is less liability to distortion, owing to the heat being distributed over the whole blank, and not localised, as is the case with the disc cutters, where one tooth is cut at a time. Also the initial stresses in the blank often cause a distortion after cutting. If a disc cutter be used it is quite likely that the points of the teeth may be out of a true circle.

When a gear is hobbed it is preferable to leave the blank slightly larger than standard size say 0·004 in. in diameter, the hob would then finish the tips of the teeth to the correct diameter and a true round. It is possible to get disc cutters with a wing on each side to accomplish the same object, but such cutters are special and costly.

In the Fellows system the hob trouble is entirely eliminated, as the cutters used are not made to any forming tool, but each tooth of each cutter is generated.

The teeth after hardening are ground by a generating device to the correct involute.

The Fellows gear shaper in its action is similar to a slotting machine, the ram carrying the cutter.

The cutter is in the form of a pinion of 12 or more teeth of true involute form. The spindle carrying the cutter in the ram is geared by change wheels to the blank mandrel. The cutter, while reciprocating, is fed into the blank the correct depth of the tooth, the blank and cutter slowly revolve together at the exact ratio between the number of teeth in the cutter and the blank being cut. The operation of cutting is completed in one revolution. One cutter only is required for any number of teeth from a pinion to a rack.

THE FELLOWS GEAR SHAPER

The Fellows Gear Shaping Machine carries a special form of cutter, having teeth in which the involute curve is generated. The cutter being itself in the form of a gear is actually used as a planing tool, and is so connected by gearing to the spindle carrying the work, that during the cutting operation it and the blank rotate slowly together, as if they were two gear wheels in mesh, the slow rotation being the feed.

The cutter is first fed radially the required depth into the blank. The continued planing during the slow rotation of the cutter and the blank generates theoretically correct gear teeth. The cutter itself is a generated gear being finished by a grinding process, which will be described later. In the above machine the operator has simply to feed the cutter to the blank, there being no centring or gauging of depth. The work is held by the face plate system, in which the work spindle, the mandrel and the work itself are drawn as closely together as if they were one piece. The precise depth of the blank is noted and the travel of the cutter adjusted to it until the full depth is reached, when both cutter and blank begin to revolve, while the cutter continues to plane out the teeth. This rotation is secured by proper gearing which insures the cutter and blank turning as though they were a pair of

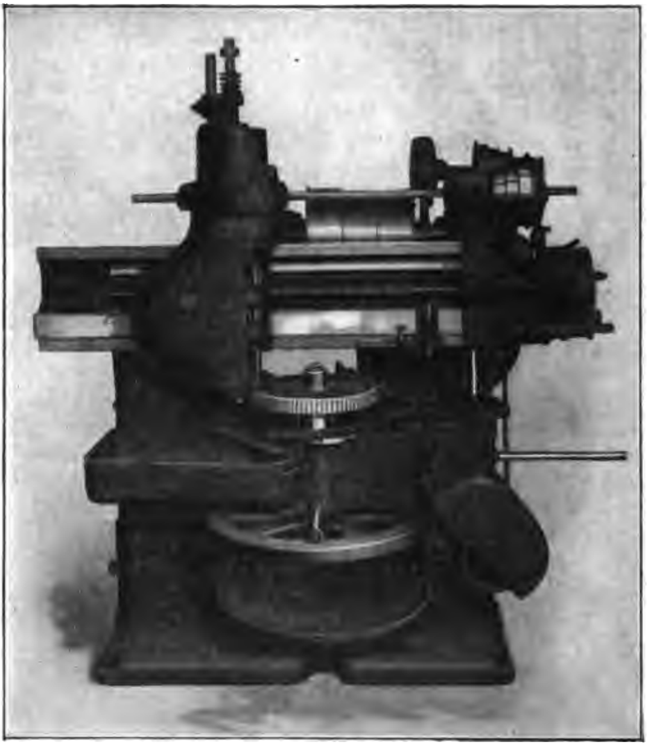


FIG. 193.—Fellows gear shaper cutting the teeth of a spur wheel.

gears. By this method, and as a result of the rotary and cutting movements, the teeth of the cutter generate conjugate teeth in the blanks, which must mesh correctly with the cutter teeth, and with any other gear of the same pitch. The cutter and work blank are shown in Fig. 191. A novel feature is given in the illustration (Fig. 192), where a gear having both external and internal teeth to be cut on the same casting are done at one setting of the work. One cutter only is used for both gears. As the gear is a plate wheel the teeth may be cut to any depth desired, even to the face, by the careful adjustment of the ram carrying the cutter. Similar work done with a single disc cutter would essentially be of a very small diameter, while the cutter would leave a portion uncut owing to the fact that it would necessarily leave its own form on the termination of its traverse (Figs. 192 and 193).

Transmitting Rotary Motion

Fig. 194 (7, 8 and 9) represent diagrammatically drawing an involute on a card attached to the lower one of a pair of discs, connected by a taut thread. Fig. 194 (8) drawing the involute on a card attached to the upper disc. Fig. 194 (9) the two cards cut out to form involute templets and used to transmit uniform motion from the lower to the upper shaft. If resistance is applied to the lower pulley so as to keep the thread taut, and the upper pulley turned in the direction of the arrow, the two pulleys will be revolved together smoothly, and a tracing point in the thread will draw an involute curve on the card, with the diameter of the lower

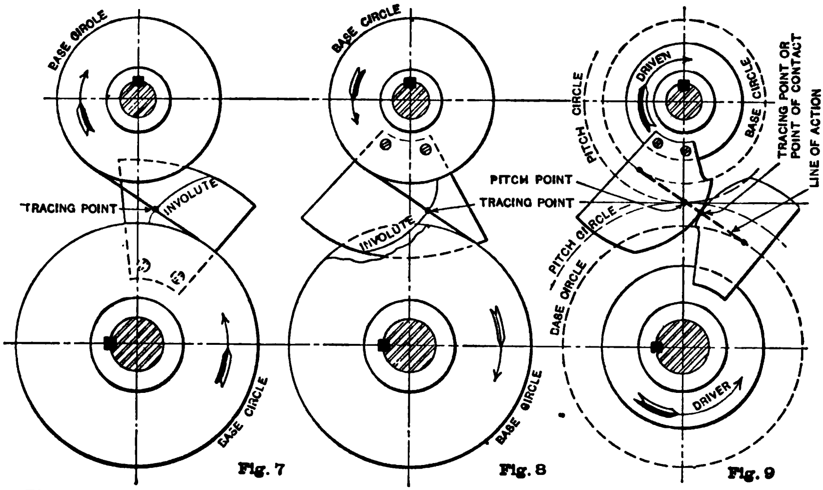


Fig. 7.—Drawing an involute on a card attached to the lower one of a pair of disks connected by a taut thread. Fig. 8.—Drawing the involute on a card attached to the upper disk. Fig. 9.—The two cards cut out to form involute templets and used to transmit uniform motion from the lower to the upper shaft.

FIG. 194.

pulley as a base circle. In the same way we may attach a card to the face of the upper pulley. If the two pulleys are rotated as before, keeping the thread taut, the same tracing point in the thread will generate an involute on the card, having the diameter of the upper pulley as a base circle. Next take a sharp knife and carefully cut the two cards along the involutes that have been drawn on them. Then attach the templets thus made in their places on the pulleys again as shown in Fig. 194 (9). If the two pulleys are rotated together by the stretched thread, as before, the tracing point will follow along the outline of the involute edges of the two templets simultaneously. It must be evident that both templets will be in continuous contact with the tracing point since they were both traced by that point. They must, therefore, be in continuous contact with each other, over the whole length of the involute curves.

Now in Fig 194 (9) the base circles and the threads are indicated by dotted lines, since the pulleys were turned down so as not to interfere with the view of the templets. But it should be plain that the driving templet will transmit motion to the driven templet with just the same motion as though the connecting thread were still there—that is to say with just the same steadiness of motion as given by the pulleys and crossed belts.

Two involute curves then will transmit steady motion from one shaft to another; and this motion may be of any desired velocity ratio, this ratio being the same as if the base circles of the involutes were pulleys connected by a crossed belt. In Fig. 194 (9) the straight portion of the thread between the two base circles is called the "line of action" because it is along the line that contact takes place. The point where line of action crosses the centre line of the two shafts is called the "pitch point." Circles drawn through this point from each shaft centre are called "pitch circles."

Using the Involute for Gear Teeth

It has been shown that the curved templets of Fig. 194 will transmit smooth uniform motion, but only for a small angle of rotation. In order to transmit continuous rotary motion there must be a new pair of involutes ready to take up the work as fast as the previous pair goes out of action. This has been done in Fig. 195, where the involutes are applied to both faces of all the teeth in a pair of gears. By having involute faces on both sides of the teeth, the gears will run in either direction.

In Fig. 195 the driving-gear is supposed to run three times as fast as the driven gear, so that the latter must have three times as many teeth as the former. There are 12 teeth in the driver, and 36 in the driven gear. The pitch circles are also made in the same ratio of 3 to 1, and of such diameters that they just fill in the required centre distance, whatever that may be. The base circles must have the same ratio. The pitch circle of the small gear is accurately stepped off into 24 divisions, one for each of its 12 teeth and 12 spaces. In the same way the pitch circle of the larger gear is spaced off into 72 divisions, for its 36 teeth and 36 spaces. Since the pitch diameter and pitch circumference of the 36 gear is three times the pitch diameter and pitch circumference of the small gear, it is evident that each tooth division of one gear will accurately fit the corresponding space divisions on the other, and *vice versâ*. The height of the teeth in each gear having been decided on, involutes are drawn through the division points on each pitch circle, extending from the base circle to the top of the tooth. These form the acting-surfaces.

The tooth outline below the base circle in each tooth space must be so formed that it will not come into contact with the point of the mating tooth. There can be no possibility of involute action, and therefore no true involute contact, below the base circle from which the involute is generated.

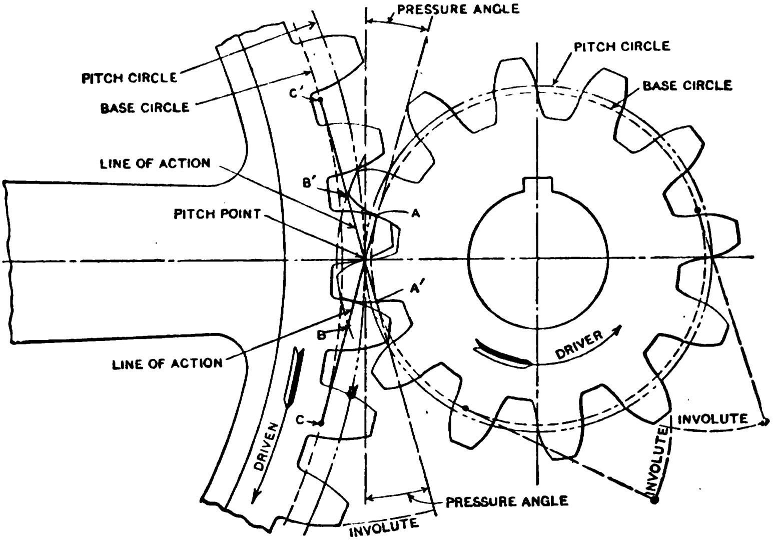


FIG. 195.—Gears whose acting tooth surfaces are formed from involute curves.

This is a point not to be lost sight of in considering gearing questions.

Mr. Humpage, of Bristol, has devised a machine for grinding the involute teeth of gear-wheels, which works on the principle of the hobbing machine. The teeth are generated simultaneously, so that distortion due to the heating of the blank is eliminated, and, as the downward feed of the abrasive wheel is very rapid, the wear is practically negligible.

For purposes of experiment an ordinary 22-inch gear hobbing machine made by his firm was chosen.

In place of the hob was substituted a cylinder of corundum, grit 50, grade M, 10 inches in diameter, and 7 inches long, having a continuous thread of 7 pitch cut upon it. The sides of the thread are straight and inclined at an angle of 30°, which is the exact shape of the hobbing cutter. The thickness of the thread on the pitch line is, however, made rather less than the correct thickness for a 7 pitch tooth. The corundum worm practically amounts to a hobbing cutter having an infinite number of teeth. The thread was roughed out in a lathe with Huntingdon Dressers in seven hours, and finished by grinding on a Greenfield Universal Tool Grinder with a carborundum wheel in twenty-one hours. It is thought that it may be possible to save much time in manufacture by moulding the thread roughly into shape. In place of driving the corundum worm through the gear box and vertical shaft of the machine, a pulley is fixed directly on the spindle of the corundum worm itself. By this means the effects of the torsion of the shafts are got rid of. The corundum worm is revolved at a speed of 2400 revolutions per minute, and it is geared up to the work table through change wheels as a hobbing machine. A rapid downward feed is provided for, and the driving-belt is led horizontally to the driving pulley to admit this. Mr. Humpage has ground up several cast-iron wheels of 7 pitch on the experimental machine. The wheels are first hobbed, but the hob is not put in to the full depth, so that a few thousandths of an inch are left on the sides of the teeth for grinding off. Before the wheels are ground, the bottoms of the teeth are cut to the full depth with a specially formed cutter. It would, of course, be far better to hob the teeth in one operation with a hob having teeth that are slightly too thin. The wheel is then put on the work mandrel, and the corundum worm moved down by hand until its centre is level with the top of the wheel to be ground.

The corundum worm is then adjusted endwise by means of a screw turned by a worm and worm wheel by which a very fine cut can be put on, so that one side of the thread touches one side of the teeth in the wheel. Owing to the thread on the corundum worm being thin, as has been explained, the other side of the thread is not in contact with the teeth. The corundum worm is then allowed to feed down automatically, grinding up one side of the teeth and generating them truly.

The machine is then stopped, the corundum worm raised by hand, and a finishing cut taken. The other sides of the teeth are ground and finished in the same way. A stream of lubricant consisting of water, soda, and oil, is kept running on the wheel to prevent glazing.

In the best results obtained so far a cast-iron wheel of 70 teeth, 7 pitch, and 1½ in. face was completely ground in eight minutes. The wear on the corundum worm appears to be very slight, about $\frac{1}{1000}$ inch in the worst part, but in the machine it is proposed to provide a carborundum wheel for touching up the corundum wheel after each cut. Mr. Humpage has found that when he grinds $\frac{1}{1000}$ in. off the corundum worm to true it up, the carborundum wheel which grinds it shows only $\frac{1}{4000}$ in. of wear, he also found that the corundum worm is only worn on three threads for about one-third of their circumference. In the finished machine an arrangement will be provided for traversing the wheel that is being ground across the face of the corundum worm like a wheel meshing with a rack, thereby wearing the corundum worm evenly.

THE GENERATION OF THE CUTTER

In Fig. 196 the cylinder A has a diameter the same as that of the pitch circle of the cutter it is desired to generate.

The top surface of bar B represents the pitch line of the rack. A is constrained to roll on B without slipping by means of the flexible steel tapes shown. E is an imaginary rack of the proper angle and pitch for the interchangeable system of teeth for which the cutter is to be made. Now if C is a blank made of wax or similar plastic material, rolling A on B will roll C in rack E, and the latter will generate the desired form of teeth in cutter C.

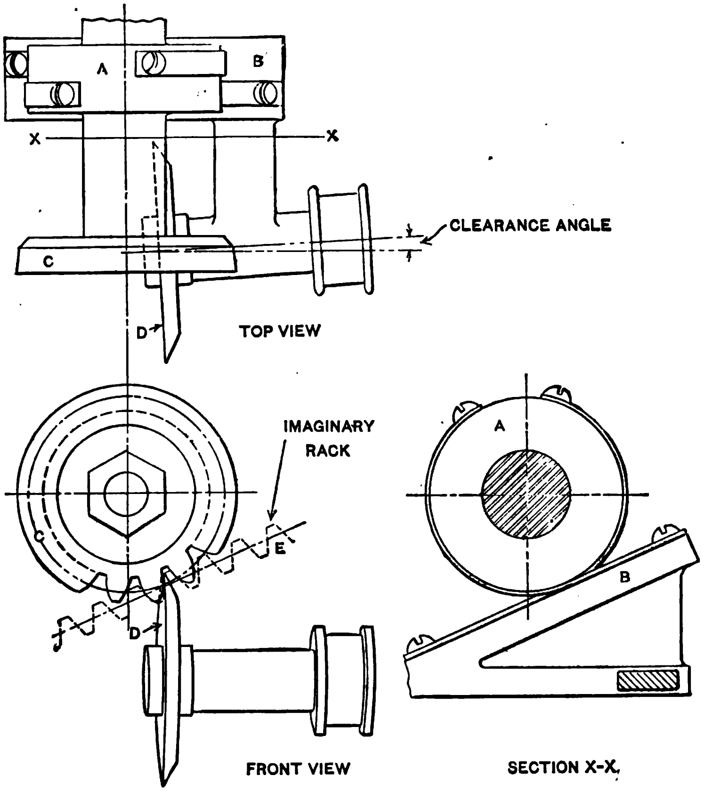


FIG. 196.—Principle of grinding machine for generating the involute teeth of the gear shaper cutter.

Suppose that C is a shaper cutter, roughed out nearly to the finished shape, and mounted on the spindle attached to A.

When this spindle is rolled up and down inclined surface B, the cylinder and tape arrangement will roll the cutter blank in unison with the imaginary rack, without any possibility of slipping.

Now let D be the carefully traced face of a grinding wheel, set exactly in line with a tooth face of E. This wheel face will then represent the face of the imaginary rack tooth with which C is meshing as it rolls, and this wheel face must then generate on the cutter the same curve that the imaginary rack would generate if cutter blank C were made of wax or other plastic material.

CUTTER GRINDING MACHINE

Fig. 196 is a skeleton diagram used for illustrating principles. In Figs. 197A and 197B are shown views of the actual cutter grinding machine in operation. In the first illustration the tooth of the cutter is just rolling into contact with the plane face of the grinding wheel, but in Fig. 197B the generating action is nearly completed, the rolling of the cutter having almost reached the position where the face of the wheel points directly towards the centre line of the cutter, and where the wheel would give the radial flank and the necessary angle of relief to each of the cutting edges. After all the teeth of the cutter have been

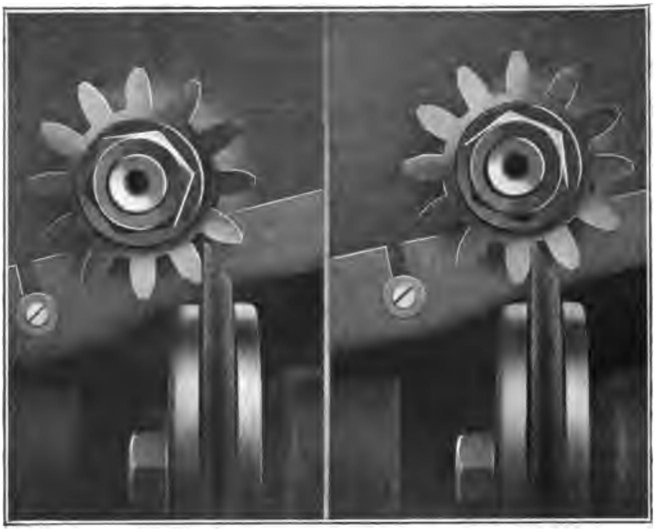


FIG. 197A.—The tooth face of a gear shaper cutter rolling into action with the plane face of a grinding wheel.

FIG. 197B.—The cutter approaching the end of its rolling movement, showing how the straight flank is obtained.

ground in this way, it is removed and reversed for finishing the other sides of the teeth. The fact that this cutter is ground to shape is a very important consideration. It means that the change of form due to the hardening process can be corrected afterwards, thus giving the true theoretical curve to the finished cutter.

THE GENERATION OF THE CUTTER BY GRINDING

It is necessary to thin the tooth of the cutter without changing the shape of the involute curve generated. This is done by setting the spindle of the wheel D at a slight angle sideways marked. (See Fig. 196, "Clearance angle" in the cut.) This does not alter the vertical angle to which plane E and the cutter are set, so the pressure angle is not changed. It merely grinds the tooth shape on a very slight twist or spiral. The importance of the flat tooth of the involute rack can now be appreciated. It enables us to generate the tooth curve from a surface which is easily obtained and accurately maintained.

A cutter can be generated complete, without copying or forming processes of any kind, giving a true originally developed involute outline for each tooth. (The tapes connecting *pitch surfaces* A and B should not be confused with the crossed belts connecting the *base circles*. They serve the same purpose of transmitting uniform motion, but the tapes of Fig. 196 do not represent the lines of action.)

THE STUB TOOTH GEAR

The two most important features in cut gearing are the securing of the nearest approach to a rolling action that it is possible to obtain, and the strongest tooth that will meet this condition. The first includes easy running, reduces the friction to the lowest point, and, consequently, has the least wear in action. The so-called standard tooth of to-day is the involute curve with the 14½ degree angle of obliquity or pressure angle. There is, however, a newer form known as the "Stub tooth."

Mr. H. S. Rowley, M.I.M.E., an authority who has experimented with various forms of gear teeth, says: "In the evolution of the involute system, 14½ degree angle of pressure was adopted as a basis, probably on account of its convenience in 'setting out,' the sine of this angle being practically one-fourth. The length of tooth should be sufficient to give an arc of contact between two meshing teeth at least equal to the pitch arc with the smallest pinions, 12 being the minimum in practice. This enables one pair of teeth to keep in contact until the next ones are in position for taking up the load. It naturally results, therefore, that there is no fixed relation between the obliquity of the line of action and the length of tooth. A length of tooth beyond that which is necessary to insure a continuity of action produces undue friction and wear, the results being obtained when the arc is from 1¼ to 1½ times the pitch arc."

One of the most valuable features of the involute curve is that the centres of two gears may be varied to such an extent that they only engage at the points and will work together in perfect contact, the lines of action and the pitch line moving with the curves, resulting only in excessive backlash. This rule, however, only holds good where both gears are above a certain number of teeth. In pinions the arc of action must not be reduced below the equivalent of the circular pitch, nor must the curve go beyond the line of interference when the centres are closed in. The 12-tooth pinion is the smallest that will have an arc of action as great as the pitch, but 11, and even 10, may be used, the error being practically negligible. Conditions which refer to spur gears apply equally to internal or annular gears, but what is tooth in the one becomes space in the other. It is possible to make two gears of which the pinion has only two teeth less than the internal. Although the subject of gearing has been investigated and discussed at great length by many mechanics, there is one phase of the subject that has received but scant attention, and this is the correlative effect of the angle of obliquity or pressure angle, and the length of the tooth upon

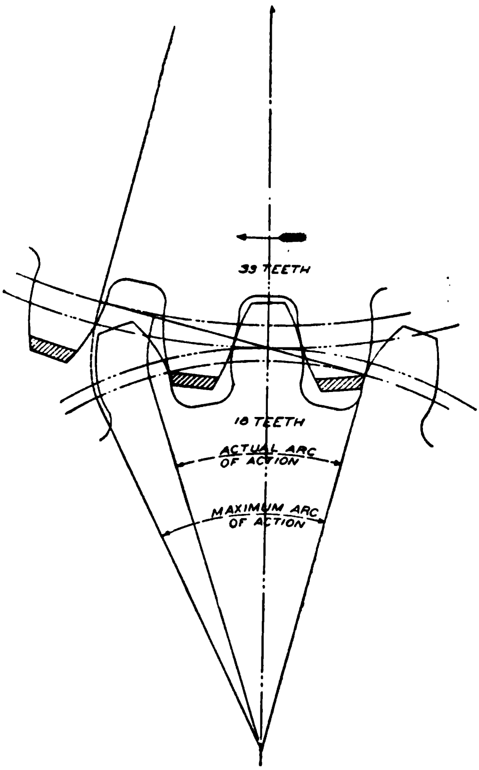


FIG. 198.—Showing comparison of arc of action 14½° angle of obliquity.

the efficiency and wearing qualities of the tooth itself. It can be shown that an excessive sliding action takes place between gears having teeth of the standard 14½ degree angle, and that by increasing this angle it is possible to so shorten the tooth that only such portions of the curve are used as will give nearly a complete rolling action.

The use of gears for the transmission of power in automobiles has, perhaps, called attention to this question more than any other line of work, and to show clearly just what this action really is, the following diagrams have been prepared for the comparison of the action of the stub tooth with that of the 14½ degree angle, using as an example the gears of the sliding transmission of an automobile.

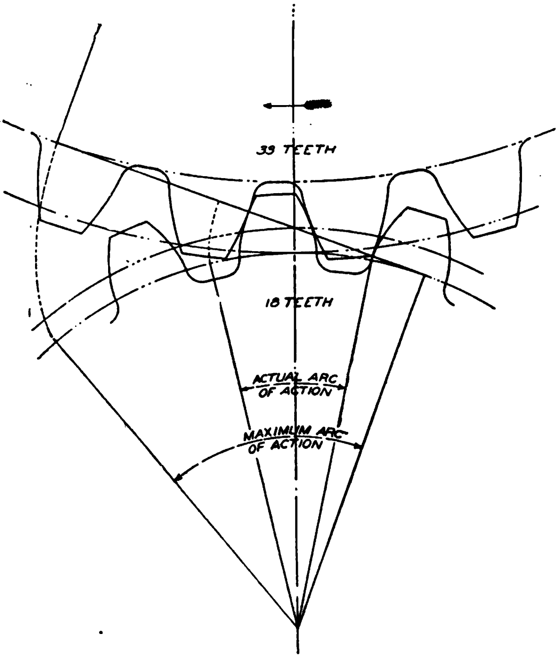


FIG. 199.—Showing comparison of arc of action 20° angle of obliquity.

The following gears have been selected as being typical of such a transmission or "gear box":—

Low gear	18–33
Second gear	26–25
Third gear	20–31
Reverse gear	14–20–31

These gears are shown assembled in Fig. 198, as the combinations 18–33 and 20–31 are very familiar; the second has been omitted; and the others will now be considered. In Fig. 198 is shown a pinion of 18 teeth engaged with a gear of 33 teeth.

The increased angle of obliquity is an essential part of the Stub-Tooth system, and with this increased angle the effective arc of motion is as long as that of the 14½ degree tooth.

It is impossible to entirely eliminate the wear between the teeth of gears working under a load; but if the wear can be evenly distributed over the entire working face of the tooth, the correct form of tooth is retained indefinitely, and a worn-out gear should, aside from the excessive backlash, run as well as a new gear. Therefore, if this wear can be evenly distributed, the durability of any gear will be increased many times.

A further advantage claimed is the increased strength of the tooth. Because of the fact that the tooth has been shortened and at the same time widened at its base, there is a very substantial gain in strength, which has been found in cases to equal 100 per cent. In Fig. 200 is shown enlarged sections of the different combinations of gears, showing the comparative strength of each form by the well-known graphical method of Wilfred Lewis. In laying out these diagrams, we first draw the normal of the involute AB from the extreme point of the tooth. From the point B, where the normal intersects the centre line, erect the parabola BC, with its base tangent to the flank of the tooth, and indicating D as the weakest section. Draw DG at right angles to the centre line, and connect B and D. Then draw DH at right angles to BD, intersecting the centre line at H. In this construction GH may be taken as the measure of the strength of the tooth.

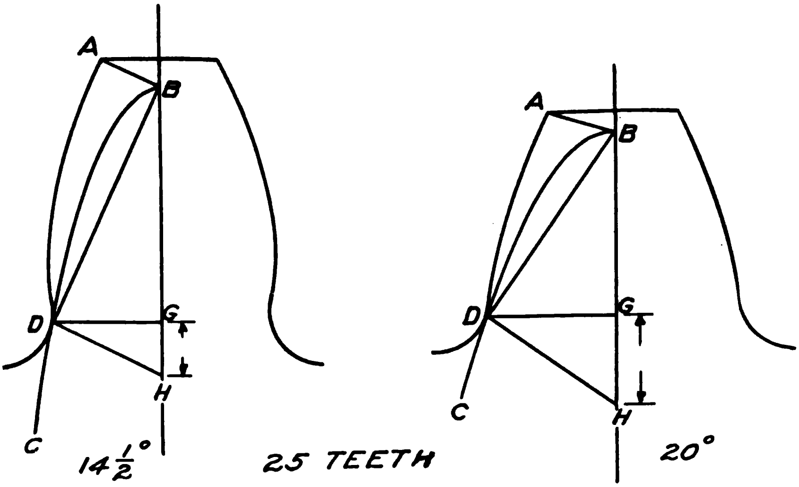


FIG. 200.—Comparison of strength of two systems of gear teeth.

A comparison of these diagrams of both the standard and stub teeth in this way shows an increase of strength in these cases of 71 to 80 per cent. for these combinations. It should also be noted that the gain in strength is greatest in the case of the smallest pinion, which is a very great advantage. This, in addition to the fact of easy running and reduced wear, should command careful consideration for the form of teeth here advocated.

Cutting Speed

Referring to the table of cutting speeds, it is found that the cutter should make 34 strokes per minute for a blank of 4 in. face. These figures are correct for cutters of carbon steel. No fast rule can be made for cutter speeds. When high-speed steel is used, the speed may be increased 50 per cent.

Feeds

Two independent feed motions are provided, a depth feed by which the saddle carrying the cutter is fed radially into the blank, and a rotary feed by which the cutter and the blank are slowly rotated in unison.

The depth feed is operated by giving to the dial gear an intermittent motion from the crank shaft.

The rotary feed turns slowly the two feed rods connecting the cutter and the blank. The rotary feed is automatically tripped by movement of the feed trip lever.

For the majority of work, the rotary feed should be engaged while the depth feed is in operation, in which case the stop pin should be out of engagement until the cutter has reached nearly to full depth, throwing in the rotary feed by hand just before the locking pin of the dial engages double-cut mechanism. As adjusted for one cut the cycle of feed operations of the gear shaper is as follows: at the beginning both the rotary and the depth feeds are in operation at the same time, at the completion of the depth cut the depth feed is disengaged and the timing mechanism thrown in. It is often necessary, however, in cutting the finest quality of gears of hard material or coarse pitches, to take two cuts, and the feed mechanism may be so adjusted that a roughing, and finishing cut will be automatically taken before the feed is tripped. Wherever possible it is recommended that the cutting be done with the upward or drawing stroke using the support over the blank wherever the diameter of the blank will permit it.

Holding the Blanks

Because of the fact that in milling gears, time is saved by cutting a long string at one setting, the idea has become established that this is desirable.

The gear shaper using a planing cutter, travels only the face of the blank, and therefore there is no advantage of long travel of the cutter. A considerable part of the trouble in cutting gears is due to the fact that the rims of the blanks are not true with the holes, and it is obvious that by reducing the number of blanks that are clamped together at one time, the effect of this error is reduced. Under ordinary conditions, the best results will be obtained by limiting the travel of the cutter to between two and three inches. Fig. 200A shows a method of holding typical automobile gears. In this case the bushings and plate are made in one piece.

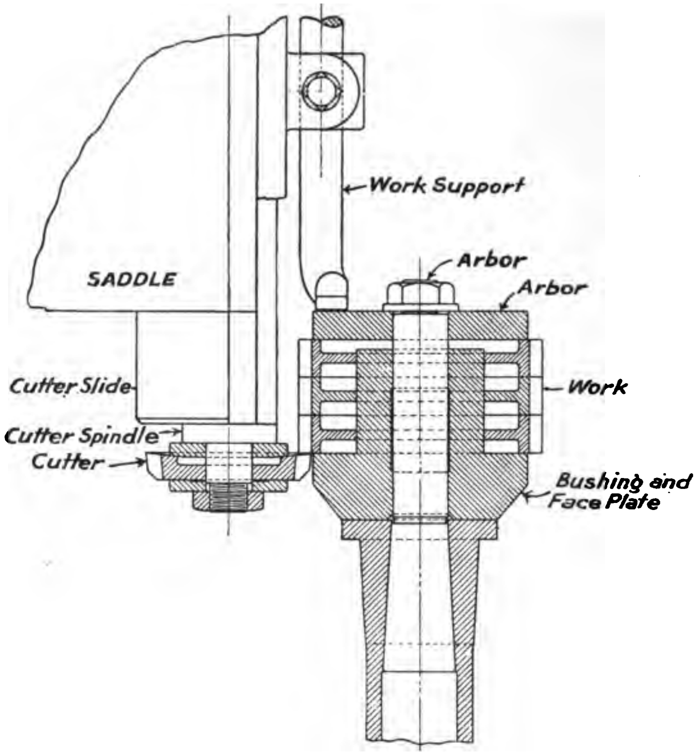


FIG. 200A.—Gear shaper and work.

It will be seen that the work support is in its right place meeting the thrust of the cutting tool, which in this case is upward. Fig. 200B shows the method of cutting the "triple gear." This type of gear is an essential part of the planetary transmission of the automobile.

In order to assemble two "planets" a tooth of each of the three gears must be in exact alignment. This is accomplished by the use of the alignment fixture, shown Fig. 200B. In the above machine the work is clamped direct to a work spindle, making the combination very stiff.

A worm and wheel reducing gear is shown in Figs. 201 and 201A. It will be seen that the worm has seven starts or leads. This gives to the worm wheel a movement of seven teeth, at each revolution of the worm shaft. It is to be noted that the shape and inclination of the worm-wheel teeth are true counterparts of the shape and inclination of the worm threads. This is a most desirable feature in gearing of this kind. The precision of this agreement is obtained by the hobbing process, actually the revolving worm, when in mesh with its mate, is or should be a duplicate of the hobbing cutter, having the same diameter and pitch, being cut and finished with a similar tool.

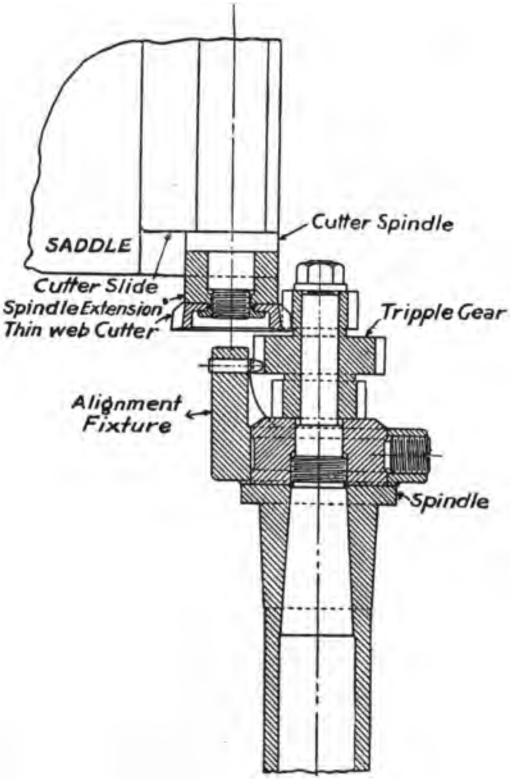


FIG. 200B.—Gear shaper cutting triple gear.

Much, however, depends upon, the relief of the hobbing cutter teeth. Unless these are in a perfect condition and hob clean, the true form will be destroyed, *i.e.* the extreme points of the wheel teeth will drag as they leave the cutter.

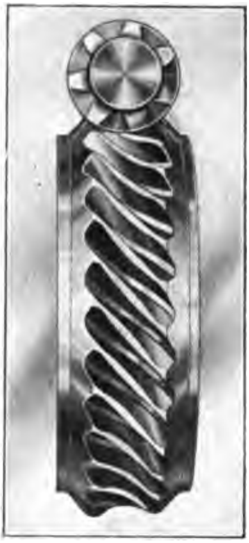


FIG. 201.—7-lead worm and wheel.

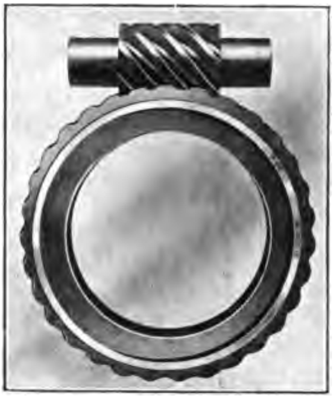


FIG. 201A.—7-lead worm and wheel.

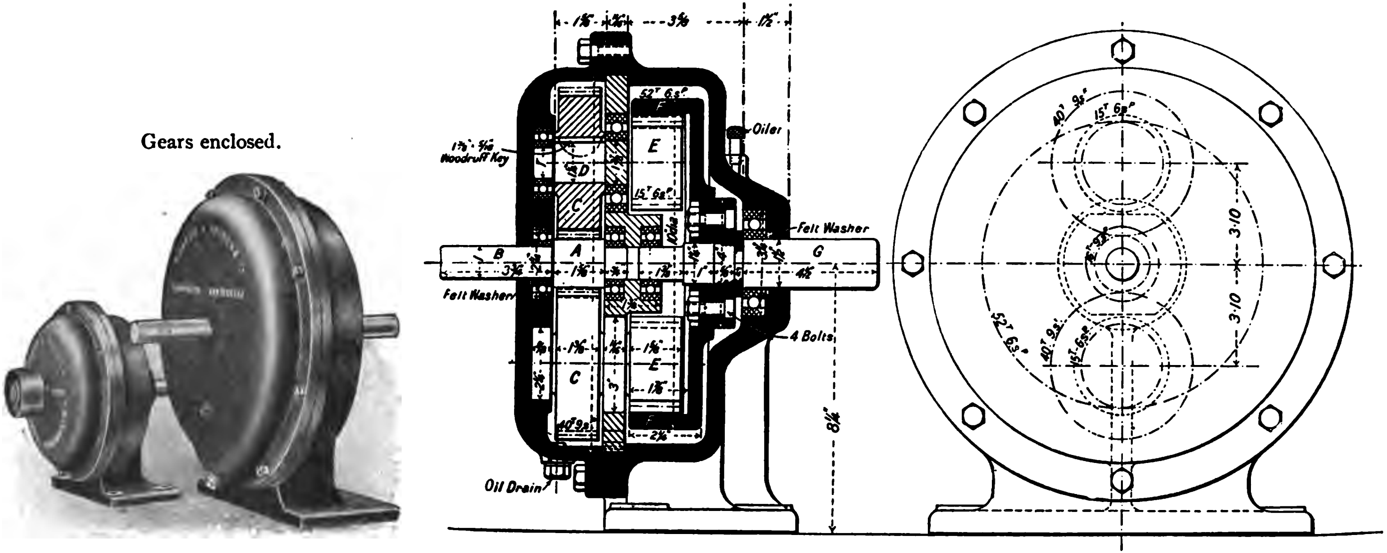
CONCENTRIC SPUR REDUCTION GEAR

A double reduction gear is shown in Fig. 202. The spur wheels are marked in the diagram. The arrangement consists of a pinion A which is forged solid with the first motion or quick running shaft B and gears with wheels C, arranged concentrically around it. These wheels C are keyed on to short shafts D, having pinions E cut solid on them. The pinions E gear with an internally toothed wheel F which is secured to the final or slow-running shaft G whose axis is in a line with the fast-running shaft B. It will be observed that all the shafts are carried on two supports, and ball bearings are used throughout. The gears are of steel, the fast-running pinions being case hardened. The gearing illustrated gives a ratio between the first and second motion shafts of $8\frac{2}{3}$ to 1. The gear is Rowley's patent, and is made by Barlow and Chidlaw, Ltd., Pendleton, Manchester.

WORM WHEELS AND WORM CUTTING

The teeth of an ordinary spur wheel are cut straight across the circumference, that is, each tooth is axially true with the bore of the wheel. Spur wheels, however, are not adapted to gear with a screw. It must be obvious that, however fine the pitch of a screw, the lead or slope of the threads must deviate from a straight line.

The larger the diameter of the worm, the less the inclination of the sides of the screw threads for a given pitch. A much greater surface contact is obtained by cutting the teeth on a twist, the inclination being



Gears enclosed.

Sectional elevation.

Arrangement of gears.

FIG. 202.—Concentric spur reducing gear.

equal to that of the screw or worm with which it is to finally engage. But even this is only a partial contact, because the teeth are only diverted and do not conform to the curve of the screw threads any more than upon the spur wheels.

What is really necessary is that the wheel teeth shall be an actual counterpart of the screw or worm precisely as a nut is an accurate counterpart of a screw. A midway between the slanting tooth and a perfectly cut worm wheel is to have the teeth made concave and cut the worm so as to gear with it. Now it will be clear that each tooth cut in this manner is distinct and apart from its neighbours, therefore in this respect it falls incomplete, because a worm is a continuous connection.

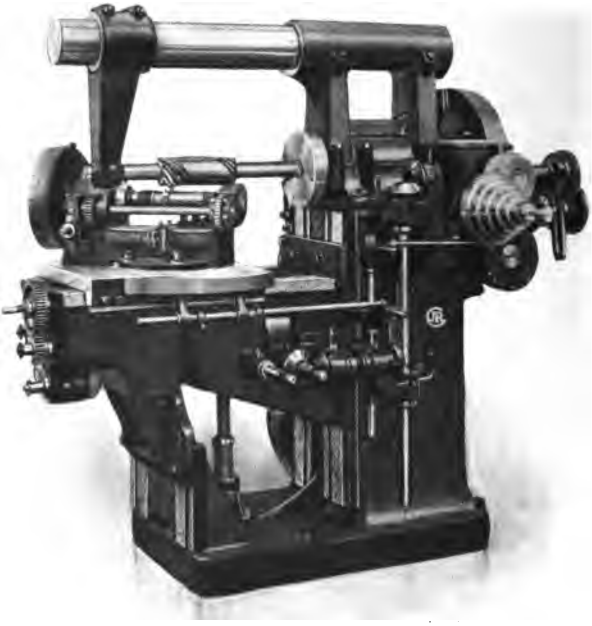


FIG. 203.—Universal gear hobbing machine. Spiral cutting in machine.

After a wheel has been turned and cut in the above manner it is finished by a hobbing cutter, of a similar pitch and diameter to the worm with which it must work.

Fig. 203 illustrates the cutting of a spiral in a universal gear hobbing machine by Reineckers. The table slides have an outside slide support; this is a notable feature, the overhang and its consequent vibration being at once checked by a counter parallel slide instead of an arm brace.

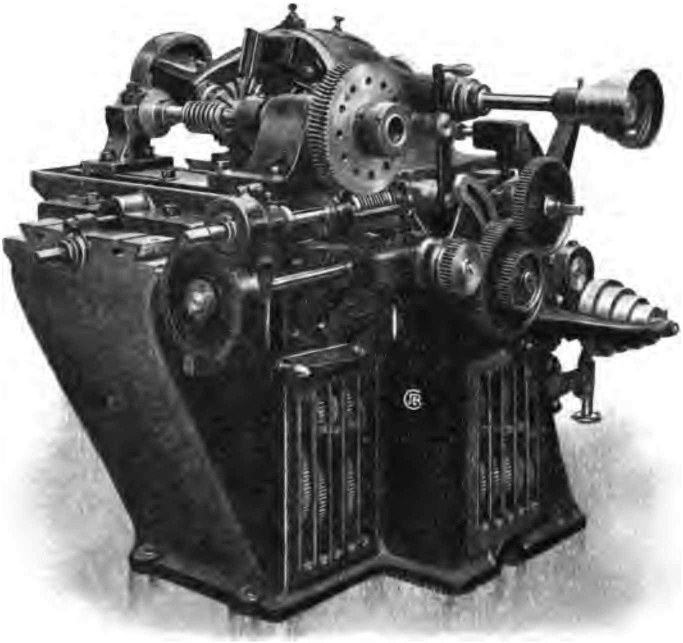


FIG. 204.—Worm milling machine.

NOTES ON WORM REDUCING GEAR

The superior power of a worm-and-wheel drive has always been admitted; but the original method of making and finishing the teeth of the worm wheels did not lend itself to this form of gearing being adopted as a general practice.

Nothing in all the mechanical devices is so powerful and positive as the worm and wheel, but its full efficiency was not accomplished until the teeth were properly cut and finally trimmed with a hobbing cutter, suitably relieved, and accurately pitched.

Since the introduction of the electric motor to drive single machine tools, or machine tools in groups, the necessity for a reliable form of reducing gear has been created. Following closely we have a further demand in the increasing automobile industries.

Among the many points desirable to be aimed at in this arrangement are: (1) Great surface contact; (2) Silent running; (3) Maximum efficiency; (4) Minimum amount of friction; and (5) High-class materials and workmanship employed in construction. All these points and many others have been obtained, so that to-day we have an efficient worm reducing gear, the worm being made of one piece of steel hardened and ground to precise shape of thread.

The best results are obtained when the gears are well lubricated, and, if possible, encased, so that there will be no possibility of grit or dust getting in the running parts. (See Rowley's patent reducing gear, Fig. 202, p. 231).

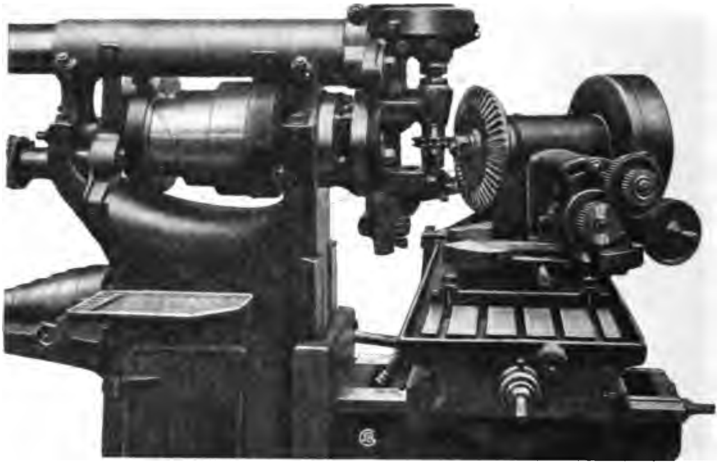


FIG. 205.—Bevel gear cutting hobbing attachment.

A bevel gear hobbing attachment is shown in Fig. 205 operating on a bevel wheel. A bevel gear planer is given in Fig. 206. This machine, which works on the Bilgrim system, gives excellent results.

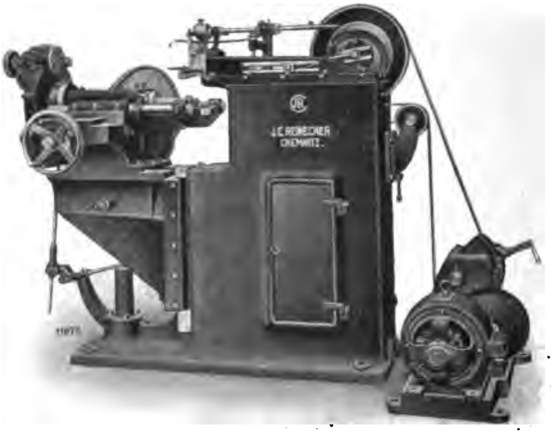


FIG. 206.—Bevel gear planing machine, motor driven.

Grinding Machines

Grinding machines are essentially in use wherever precise methods of working are adopted, or interchangeable parts are manufactured. A typical form of machine is illustrated in Fig. 207 for grinding spindles, cutters, mandrels, standard gauges, and numerous other tools in the tool room. It is also used as a manufacturing machine for grinding the most accurate work between two centres, either from mild steel stock, or work secured to the jaw chuck or directly to the machine table as desired.

There are many special features and improvements to facilitate the quick handling of the machine, and any desired rate of feed may be obtained to suit the work speed by the simple movement of a lever without in any way stopping the grinding wheel. The ways of the bed and wheel stand are covered and are self-oiling. When taper pieces are to be ground the swivel table may be set by the scale to any degree, that is, to any particular angle to the ways of the bed. In this way the true alignment of the headstock centre is maintained.

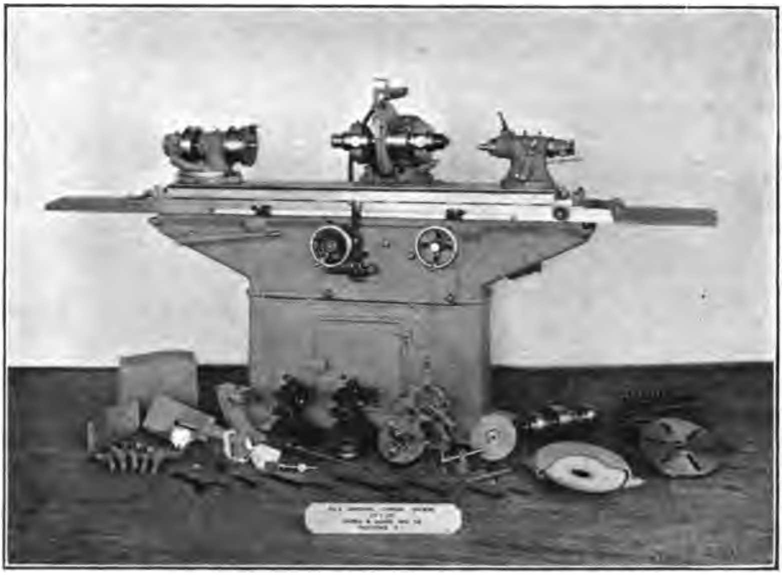


FIG. 207.—Universal grinding machine.

There are two changes of spindle speed—2666 and 3535 revs. per minute—also eight changes of work speed, varying from 75 to 670 revs. per minute.

Messrs. Brown and Sharpe, who were pioneers in this form of grinding machine, show fixtures for internal grinding, jaw chucks, and face plate, to which pieces may be secured. Various adjustable rests which may be so adjusted as to give a positive support to the work, keeping it true whilst being ground, are also included in the equipment. There are two changes of driving speed—280 to 295 revolutions—for the counter shaft.

The cut on the work is put on by an automatic cross feed, thus making it possible to grind numbers of similar pieces to definite gauge sizes without further setting. When the work is finished the automatic mechanism drops out of gear. The range of this feed is from 0·00025 in. to 0·004 in. at each reversal.

GRINDING WHEELS

Cutting tools, even when made of the hardest and toughest of modern steels, cannot hold in competition with grinding wheels on many classes of work which was formerly tooled over. The process of manufacture of grinding wheels is most interesting, and great as the strides in the capacity of modern tools of air-hardened steel have been, the grinding wheel is equally improved in its cutting powers and in those features which go to make the cutting powers more enduring. The ideal grinding wheel should automatically sharpen itself when operating on a piece of metal, so that the correct temper rather than extreme hardness or extreme softness is desired (Fig. 208).

Grinding is really a cutting process. The hard, sharp particles projecting from the working face of the grinding wheel act as cutting tools, each particle cutting its own minute chip. Under the microscope these chips resemble those removed by the different shaped lathe and planer tools. These small, sharp cutting points become dull from use after a while, just as the lathe tool becomes dull. They must fracture and break away from the bond which holds them together as they become dull, and at the right time, thus making way for the new cutting points to do their work.

If the abrasive grain tears away from the bond without fracturing or before it has done its share of cutting, the wheel wastes away. If the bonding strength of the wheel, better known as the grade, is too hard, or the grain too tough, the cutting particles become dull and the wheel glazes or burns the work. Efficiency, therefore, is not dependent upon either hardness, temper, or toughness alone, but upon the right combination as found in alundum.

While the right degree of hardness is an essential for good grinding material, it is not the sole, nor even the chief essential. This is illustrated by the fact that in the cutting of metals the hardest tools are not always the most efficient, and that the temper of tools must vary in accordance with the work to be done.

TABLE FOR SELECTION OF GRADES

Class of work.	No. of grain or degree of coarseness usually employed.	Grade letters or degrees of hardness usually furnished.
Large cast iron and steel castings	12 to 20	Q to U
Small ,, ,, ,,	20 ,, 30	P ,, R
Large malleable iron castings	14 ,, 20	O ,, U
Small ,, ,, ,,	20 ,, 30	P ,, U
Chilled iron castings	20 ,, 30	P ,, U
Wrought iron	12 ,, 30	P ,, U
Brass and bronze castings	20 ,, 36	N ,, Q
Rough work in general	16 ,, 30	P ,, R
General machine shop use	24 ,, 46	O ,, P
Lathe and planer tools	24 ,, 46	L ,, P
Small tools	36 ,,100	N ,, P
Wood-working tools	36 ,, 60	J ,, N
Twist drills (hand grinding)	36 ,, 60	M ,, N
,, (special machines)	46 ,, 60	K ,, M
Reamers, taps, milling cutters, etc. (hand grinding)	46 ,,100	M ,, P
,, ,, ,, (special machines)	46 ,, 80	J ,, M
Drop forgings	20 ,, 30	P ,, R
Gumming and sharpening saws	36 ,, 60	M ,, N
Car wheel grinding	20 ,, 30	L ,, P

Extreme toughness, or resistance to crushing pressure of the grain is not an essential. Chilled special steels have this quality in a high degree, but particles of steel would not make a practical grinding wheel if bonded together. The grain must possess such a combination of temper and hardness that it will stand until its cutting points becoming dulled, break at the right time and present new cutting edges. It should break with a sharp crisp fracture, the character of which depends upon the physical formation of the grain, its structure, and crystallisation.

One of the most important requisites in an abrasive is uniformity, it being necessary to secure constant efficiency of grade and temper in wheels, also, that they can be accurately duplicated. It is claimed that alundum contains these features in a very high degree. These wheels are made by three processes, viz. vitrified silicate, or semi-vitrified and elastic.

TABLE OF GRINDING WHEEL SPEEDS

Diameter wheel.	Millimetres.	Rev. per minute for surface speed of 4000 feet, or 1200 metres.	Rev. per minute for surface speed of 5000 feet, or 1500 metres.	Rev. per minute for surface speed of 6000 feet, or 1800 metres.
inch	about			
1	25	15,279	19,099	22,918
2	50	7,639	9,549	11,459
3	75	5,093	6,366	7,639
4	100	3,820	4,775	5,730
5	125	3,056	3,820	4,584
6	150	2,546	3,183	3,820
7	175	2,183	2,728	3,274
8	200	1,910	2,387	2,865
10	250	1,528	1,910	2,292
12	305	1,273	1,592	1,910
14	355	1,091	1,364	1,637
16	405	955	1,194	1,432
18	455	849	1,061	1,273
20	505	764	955	1,146
22	515	694	868	1,042
24	610	637	796	955
26	660	586	733	879
28	710	546	683	819
30	760	509	637	764
32	810	477	596	716
34	860	449	561	674
36	910	424	531	637
38	965	402	503	603
40	1015	382	478	573
42	1065	364	455	546
44	1115	347	434	521
46	1165	332	415	498
48	1220	318	397	477
50	1270	306	383	459
52	1320	294	369	441
54	1370	283	354	425
56	1420	273	341	410
58	1470	264	330	396
60	1520	255	319	383

The R. P. M. at which wheels are run is dependent on conditions and style of machine and the work to be ground.

Wheels are run in actual practice from 4000 to 6000 feet per minute.

All wheels above five inches diameter are tested at a speed of 9000 to 10,000 surface feet per minute.

Fig. 208 shows the method of mounting a grinding wheel. The flanges should have a bearing against the sides of the wheel near the outer edge only. They are turned away from near the edge to their centres leaving plenty of clearance. The flanges should be about half the diameter of the wheel, and a washer of pulp or rubber should be placed between the wheel and the flanges. The inside flange is keyed to the spindle, and the wheels are fitted with a leaden bushing, the bore of which passes easily over the spindle. In no case should a wheel be forced on to the spindle, since the expansion of a spindle through a heated bearing would cause trouble in the mounting. The surface speed of the wheels should be kept constant as the grinding wheel wears down. This may be accomplished by having a variable speed countershaft or cone pulleys on the spindle of the grinder, or a reduced wheel may be transferred to a machine of smaller size which runs at a faster speed. Fig. 211 illustrates a bench-grinding machine for tools.

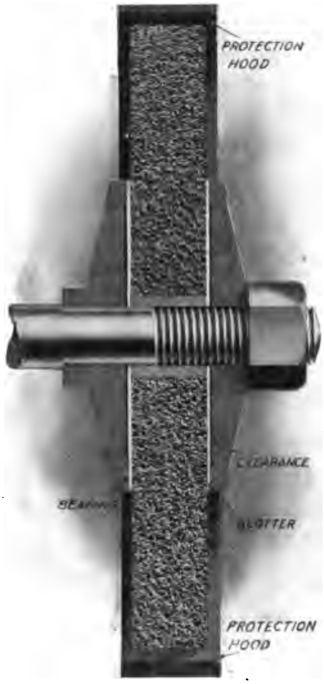


FIG. 208.—Mounting a wheel.

RULES FOR OBTAINING SURFACE SPEEDS

To find surface speed in feet, per minute, of a wheel:

RULE:—Multiply the circumference (see table below) by its revolutions per minute.

EXAMPLE:—A wheel 24 in. diameter makes 796 R. P. M. What is the surface speed, in feet, per minute?

6·283 × 796 equals 5000 feet surface speed.

Surface speed and diameter of wheel being given, to find number of revolutions of wheel spindle.

RULE:—Divide surface speed in feet, per minute, by the circumference. (See table below.)

EXAMPLE:—A wheel 20 in. diameter is to be run 6000 feet surface speed per minute. How many revolutions should the wheel make?

6000 ÷ 5·236 = 1146, number of R. P. M. wheel should make.

TABLE OF CIRCUMFERENCES.

Diam. of wheel in inches.	Circum. of wheel in feet.	Diam. of wheel in inches.	Circum. of wheel in feet.	Diam. of wheel in inches.	Circum. of wheel in feet.
1	·262	25	6·546	49	12·828
2	·524	26	6·807	50	13·090
3	·785	27	7·069	51	13·352
4	1·047	28	7·330	52	13·613
5	1·309	29	7·592	53	13·875
6	1·571	30	7·854	54	14·137
7	1·833	31	8·116	55	14·499
8	2·094	32	8·377	56	14·661
9	2·356	33	8·639	57	14·923
10	2·618	34	8·901	58	15·184
11	2·880	35	9·163	59	15·446
12	3·142	36	9·425	60	15·708
13	3·403	37	9·687	61	15·970
14	3·665	38	9·948	62	16·232
15	3·927	39	10·210	63	16·493
16	4·189	40	10·472	64	16·755
17	4·451	41	10·734	65	17·017
18	4·712	42	10·996	66	17·279
19	4·974	43	11·257	67	17·541
20	5·236	44	11·519	68	17·802
21	5·498	45	11·781	69	18·064
22	5·760	46	12·043	70	18·326
23	6·021	47	12·305	71	18·588
24	6·283	48	12·566	72	18·850

EXPLANATION OF "GRAIN" AND "GRINDING WHEELS"

Grinding wheels are made in many combinations of coarseness and hardness to meet the variety of conditions under which they are used.

"*Grain.*"—The size or number of the abrasive grain used determines the wheel's degree of coarseness. The cutting material must be crushed and graded to many sizes. The numbers employed in Norton wheels, to designate the sizes of grain are 10, 12, 14, 16, 20, 24, 30, 36, 46, 50, 60, 70, 80, 90, 100, 120, 150, 180, and 200. Finer grades of alundum known as flours, and designated as F, FF, FFF, and XF are also used, although not so much in the manufacture of wheels as for rubbing and sharpening stones.

By No. 10 grain is meant a size that will pass through a grading sieve having 10 meshes to the linear inch. No. 30 grain, 30 meshes. No. 40 grain, 40 meshes, etc.

"*Grade*" means degree of hardness of the wheel, or resistance of the cutting particles under pressure. A wheel from which the cutting particles are easily broken, causing it to wear away rapidly, is called soft, one which retains its particles longer is called hard. Wheels are graded from soft to hard, the grade being denoted by the letters of the alphabet.

When a wheel is of the proper grade for grinding any material it will automatically furnish new cutting points as fast as those in use become dull. In other words, the ideal wheel for any work will automatically sharpen itself.

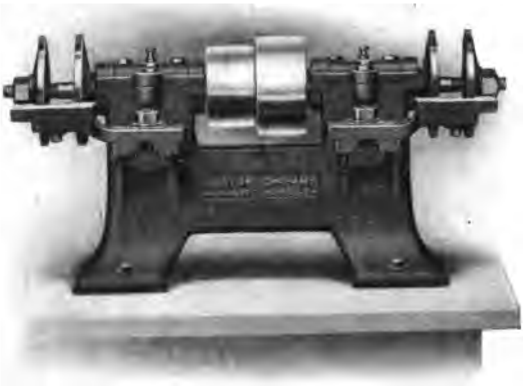


FIG. 209.—Bench grinding machine.

Example.—A 20-M grinding wheel is one in which No. 20 grain cutting material is used, and its degree of hardness is "M."

"NORTON" GRADE LIST

The following grade list is used to designate the degree of hardness of vitrified and silicate wheels: E.F.G.H., soft; I.J.K.L., medium soft; M.N.O.P., medium; Q.R.S.T., medium hard; U.V.W.X., hard; Y.Z., extremely hard. The intermediate letters between those designated as soft, medium soft, etc., indicate so many degrees harder or softer, *e.g.* L is one grade or degree soften than medium: O = two degrees harder than medium, but not quite medium hard.

Elastic wheels are graded as follows: 1, 1½, 2, 2½, 3, 4, 5, and 6. Grade 1 is the softest, and grade 6 the hardest.

GRINDING LATHE CENTRES IN THE TOOL ROOM, ETC.

It is of the greatest importance in every machine shop, for the production of good work, that a common angle for all centres should be maintained, whichever angle for the centre point is adopted. If this is rigidly carried out, standard mandrels will run perfectly true in every lathe, because by this system each lathe's centre can be duplicated and stocked in the tool room. A great saving of time and annoyance will also be effected, if the lathe poppets and spindles are all bored and reamed to a universal size and taper, such as the Morse taper for twist drills, *i.e.* all 6-inch centre lathes will be bored alike, and 8-inch lathes alike, although the diameter may proportionately increase as do the taper shanks of twist drills, and so on for larger centres. In the tool room, therefore, a centre grinding machine will be kept and all centres ground to a set angle, precisely true at the point; thus the workman will be able to take a pair of blunted centres for re-grinding and obtain a pair of sharp pointed ones with no further delay. Apart from the economy in thus keeping the lathes running, the centres will be maintained at a definite angle. There will be no variation in the accuracy of the tool room lathe spindle, because the extremely light duties can in no way interfere with the true running of the bore, in which each centre in turn is housed. Hardened bushing of various internal sizes will be necessary for the lathe centres of a general machine shop. Care must always be given to see that the centres in the work are properly "bottomed." A parallel drill run down the root of the hole will suffice, but better results are obtained by the use of a "Slocomb" drill which has the combined cone- and root-forming parallel in one piece, by this arrangement the holes are always drilled concentrically.

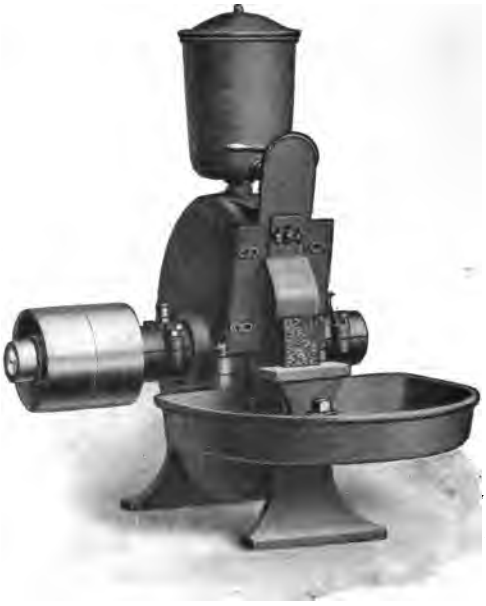


FIG. 210.—Tool grinder.

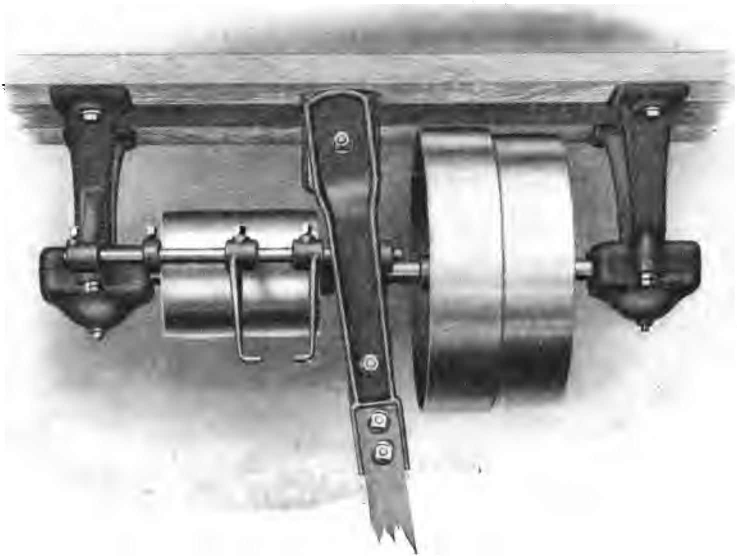


FIG. 211.

NOTES ON THE RATCHET BRACE AND PORTABLE DRILL

The engineers' ratchet brace is provided with a wheel keyed to a spindle at whose extremity a drill may be fitted in either a square or Morse tapered hole. The ratchet wheel has saw-like teeth, which are actuated by a click or pawl pivoted to a lever which is housed on the spindle for an axis. A spring presses on the click so that when the lever is moved to the left the lever is moved with it, but when moved to the right the click rides over the teeth and the wheel remains at rest. The "down feed" or advance of the drill is obtained by means of a screw and nut. Frequently the screw is cut on one end of the same spindle, while the nut may be a blind one having its opposite end reduced to a conical point which should be axially true with the point of the drill.

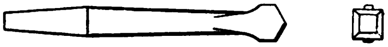


FIG. 212.—Hand-forged drill.

To start the drill cutting the nut is held while the lever is rotated just until a greater effort is needed to move it. Very hard metal can be drilled only by a fine feed. In some cases two or three complete revolutions of the lever must be allowed for one small amount of feed, but soft iron and mild steel can be fed at each revolution. The drill may be a forged one (Fig. 212), and filed up to fit the squared taper hole in the spindle. These hand-forged drills are easily made, fitted and mended after breakage. In an improved form of brace, provision is made for twist drills having Morse taper shanks. This type is preferable in many respects. The drills are straight, concentric and true fitting in the bored holder. There are sockets provided so that

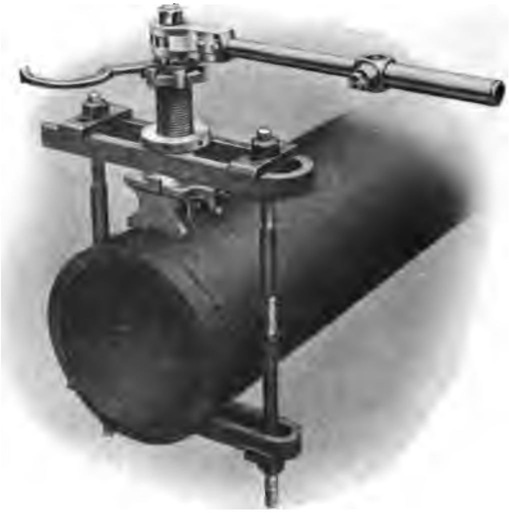


FIG. 213.

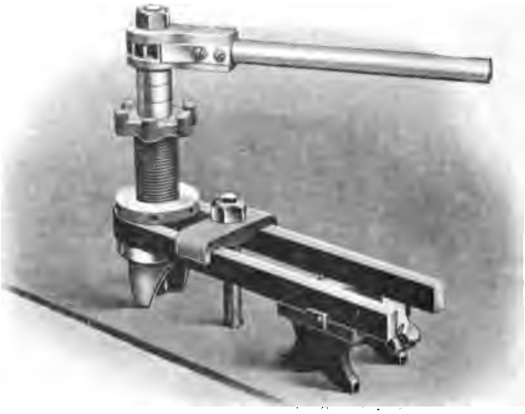


FIG. 214.

various sizes of drills may be used. In drilling blind holes it is most important to measure the length to be drilled before commencing and to mark the drill.

In drilling holes clear through a piece of metal, the feed must be given cautiously or one lip may get through while the other is cutting, and so foul the drill and probably cause it to break. An improved form by the Alexander Engineering Co. is given in Figs. 213, 214, adaptable for drilling pipes, plates, flanges, girders, etc. The parts which are of steel are adjustable, so that the drill may be rigged up anywhere; the thrust is taken on ball bearings. It is fitted with rotary and ratchet motion and ratchet feed. Fig. 213 shows the arrangement when drilling a pipe. Fig. 214 shows the drill operating on a plate.

MAKING A RATCHET BRACE

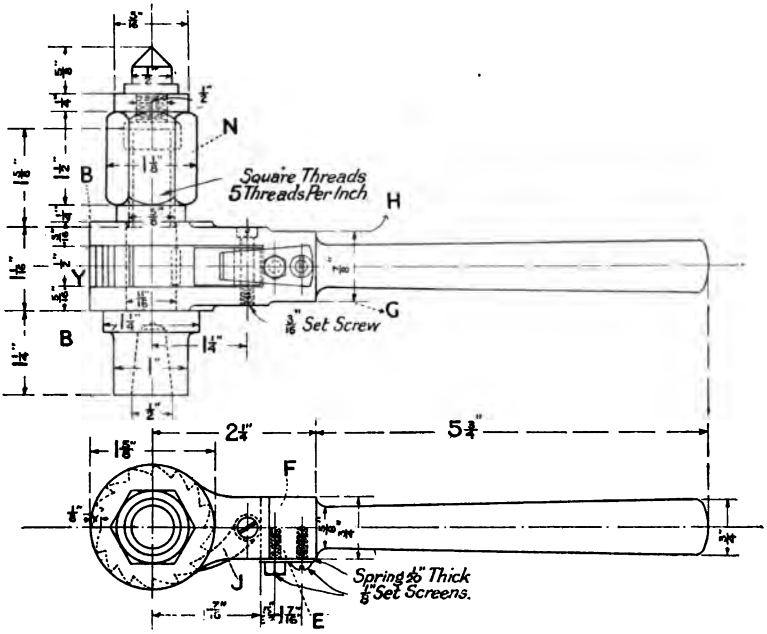


FIG. 215.—Ratchet brace.

CUTTING OFF AND ROUGHING

The handle should be a forging, or if not it may be cut out of a steel bar from the solid. By first sawing off a piece 2 in. × 9 in., and centring the ends, and rough turning one end for rachet head, a mark may then be put, showing the lengths of handle, and a further one at a distance of 2 in. for the part to hold the catch and spring.

SETTING OUT

The piece may now be set out for milling the faces BB to $1\frac{1}{16}$ in. between them, also the faces at right angles to $1\frac{1}{8}$ in., and the reduced portion EF and GH to $\frac{3}{4}$ in. and $\frac{7}{8}$ in. respectively. All these lines may be marked out while the work is set true to the turned centres. The position of the ratchet wheel may now be decided by scribing two lines at $\frac{1}{2}$ in. apart. All lines should be centre popped. The work may now be supported by fixing on the horizontal milling machine on parallel or Vee blocks, while "twin mills" are employed to reduce the sides to $1\frac{1}{8}$ in. apart. A single cut, $\frac{1}{2}$ in. wide, will be passed down to make room for the ratchet wheel at Y. There is now a hole of $\frac{11}{16}$ in. to be bored and reamed, and a small boss on either side to be turned to $1\frac{5}{8}$ in. diameter. The hexagon nut N, if well forged, will not need tooling over, but may be made $1\frac{1}{8}$ in. across the corners at the vice by filing. A gauge should be used to test the position of the flats so that they will be alike and relatively true to angle. The rachet wheel is bored $\frac{11}{16}$ in. diameter, and has sixteen teeth; these will be cut with a milling cutter, and the pawl J filed up to fit precisely. The square thread on the steel shank is now ready for cutting. This we will presume can be done in a lathe having a guide screw of $\frac{1}{4}$ in. pitch; $\frac{5}{4}$ is the ratio of the screw to be cut with the guide screw, therefore $\frac{5}{4} \times \frac{10}{10}$ gives $\frac{50}{40}$, the change wheels required. Now a $\frac{5}{8}$ in. square thread tap will be just right to act as a tool gauge. There will be a tool to make $\frac{1}{10}$ in. wide, or just to fit the space between two threads in the tap. The nut is shown cut and recessed; therefore, for first-class work it should be chucked in a lathe, a hole bored through the piece $\frac{27}{64}$ in. diameter for the front end, $\frac{1}{2}$ in. tap Vee thread. Beyond this the recess must be cut, and the work reversed in the lathe for re-boring the hole for the square thread nut. It is essential that the square thread be truly concentric with the bore. To effect this, a few cuts should be made with the aid of the change wheels until the *second* tap will enter. This being done, the lathe must be stopped and the poppet centre used to hold up the shank truly, while the tap is slowly rotated by its wrench. During this process the lathe is at rest, but after each movement, *i.e.* about one-quarter turn of the wrench, the belt is pulled round just enough for a fresh start. Care must be given, or the end of the tap will collide with the end of the recess, and if this is allowed the tap will be fractured, or the previously cut Vee thread spoiled. The cast-steel centre carries at its opposite end a $\frac{1}{2}$-in. Vee thread. This is also screw cut, and made a very tight fit by chasing. At the opposite end of the square thread screw the hole must be made for the drill. This is shown to be taper. The practice is to bore the hole in the lathe to the size shown at the root, and open the mouth gradually until the correct taper and diameter are obtained. In setting the lathe for this a plug turned to the correct dimensions will serve as a gauge. The spring and pawl can next be finished and fixed while the other parts are in place.

After this the brace is dissembled, and the various parts, that is, all working parts, hardened. The spring will be tempered to a purple or blue colour. The screw and nut, and the ratchet wheel, should be "case" hardened, or at least hardened with the aid of cyanide of potash.

It may be pointed out that hardening means giving the articles a coat of hard steel; the thickness of the coat is proportional to the time the articles are subjected to the absorption of carbon from the material used. "Skin hardening" is obtained by heating up the articles, and smearing them with prussiate of potash. Time, several minutes. Case hardening is effected by mixing hardening compounds with the work in a box, and heating them; time = several hours.

THE APPLICATION OF THE RATCHET TO THE FEED-MOTION FOR A SHAPING MACHINE

An ordinary toothed pinion may be substituted for the saw-like ratchet wheel, fitted and keyed to the saddle feed-screw. Unlike the brace already described, the machine may be used while this ratchet motion is at rest, but when at work it is automatically fed. In this arrangement the feed is put on at precise intervals, *i.e.* after the completion of the cutting stroke, and immediately before the commencement of a new one.

A vibrating link is moved by a connecting rod attached at its opposite end to a revolving wheel. The catch or pawl is pivoted near the ratchet pinion, and may be instantly engaged or withdrawn. The ratchet may move one, two, or more teeth at one stroke, according to the position of the fixing of the connecting rod. In this way a fine, medium, or coarse traverse may be obtained for the cutting tool.

The axle on which the pawl rides is provided with three flats, and the pawl has at right angles to its bore a hole drilled, into which is inserted a special spring. Above this and pressing the spring down on the axle is a set screw, which also serves to keep the spring in place; thus when the machine is at rest the pawl is kept upright, *i.e.* clear of the pinion, and may be lowered to the right or left according to the direction of the traverse required. In the heavy type of machines there are a couple of pawls riding on the same axis, one on each side of the lever, with a pinion adapted to each; this reduces the pull on any given tooth. To communicate motion to the table feed-screws in a slotting machine, a somewhat similar link and ratchet is employed, the advance being proportional to the swing of the arm to which the pawl is pivoted, that is, the farther away the connected parts are the more teeth are turned and, as a consequence, the coarser the traverse.

A vibrating link is shown in Fig. 110, in which an ordinary $\frac{5}{16}$ in. pitch wheel is used for the medium.

JOINING OF METALS BY WELDING

In order to construct engines, machines, and other built up work, many parts are made of materials which will unite or form a permanent joint. These joints are sometimes made in such a manner as to defy separation, such as the welding of bars or rods of iron and steel together to form one piece. To successfully unite iron or steel bars they must be thoroughly heated and hammered into a suitable shape, then re-heated until the metal begins to fuse; at this stage both bars are removed from the fire to the anvil and quickly brushed, then instantly one piece is laid on the other and struck with light, but rapid, blows, until the two pieces become one, the blows getting heavier as the work begins to cool down. After the first few blows on the scarf top and sides the bar is rotated slowly, so that the hammering shall produce an equally sound weld at every point. Rectangular bars are turned, so as to offer each face in turn; all this, of course, is done with the least possible delay. Much, however, depends upon the judgment of the smith and of the striker too, that is, they must act quickly and in unison. In the first place the coke should be small, and the fire kept clean and free from slag. Each bar must be "upset" and "fullered down," and afterwards bent, so as to present a convex surface, then when the bars are brought in contact the central portion of each will touch first, and the top and bottom of each scarf will be hammered until a proper joint is effected. The reason for upsetting the bars is to keep them from losing their original dimensions, because the bars quickly oxidise, and as the scale drops off during the process of hammering, the diameter would not "hold up" to size during the machinery stages.

A short shaft can usually be lengthened satisfactorily by forming a scarf joint, but long shafts may be united by forming a butt weld, or a long shaft may be just increased a little by a dab, that is, by welding a rectangular bar on one end of the shaft. Steel is not so easily welded as wrought iron, since it comes plastic at a lower temperature, also it is partly granular and, if slightly over-heated, loses its power of cohesion. Struck at such a temperature, it will fly or crumble away in fragments, Mild steel, therefore, must be very slowly and thoroughly heated (soaked), and when quite ready for welding the blows may be rapidly delivered, but they certainly must be light at first, for the reason given above, until the temperature has been lowered.

BRAZING

Brazing is the joining of two parts of the same piece or of some other material together by what is termed "spelter" (a specially soft form of brass). The brazing spelter may be in fine dust, or in the form of a strip or ribbon.

The articles to be brazed are cleansed and heated, preferably with a blow pipe, then borax is put along the joint and the spelter is carefully added, the borax and spelter are in some cases mixed beforehand, to prevent waste, the heat is increased until the spelter commences to run, then the air blast is stopped, and the work allowed to cool down. There are in some cases, such as in cycle frame joints, and similar parts of a repetitionary character pans containing molten spelter into which the various joints are dipped. This latter method proves to be most satisfactory in the filling up of every part, moreover, as the frame is removed the surplus spelter drips into the pan, thus leaving the subsequent dressing of the joints free from lumps, there being practically a very thin and uniform wash to be removed on the emery wheel, and final buffing wheel.

SOLDERING

Soldering is the seaming up of joints of tin, copper, brass, and other metal parts by mixing them as desired, or they may be of the same material. The parts are made quite clean and a flux is laid on such as resin, fluxite, or killed spirits according to the character of the work in hand. The flux helps the solder to flow. A copper bit or "soldering iron" is "tinned" and *heated just sufficiently to melt a little solder from a "stick,"* this drop of molten metal is then gently conveyed on the end of the iron and deposited along the seam to be soldered. The heat of the iron warms up the parts and assists the solder to the more readily flow.

RIVETING

Riveting is a term given to the joining of two pieces of metal by means of a pin or rivet. The materials suitable for this method of fastening are wrought iron, mild steel, and copper. Usually the rivets are made from rods of similar materials.

The pieces are prepared to receive the rivets by punching or by drilling holes. Drilled holes are the best, because the metal around the holes becomes distorted by punching, also drilled holes are more accurately located, and the rivets therefore fill the holes better. Rivets are of four kinds, pan-headed, cup-headed, conical-headed, also headless. There is, however, a counter-sink made on both pieces and the rivet is made to flow into these, leaving the outer surface even. In the headed rivets the head is formed on one end in the original manufacture, leaving a similar head to be formed by hammering or by squeezing. There are two advantages in putting red hot rivets into work such as boilers and structural iron work, because the hot rivet is plastic and yields to pressure when forming the head, also, owing to the expansion of metals by heat, the rivet is longer when first made, but in cooling shortens and thereby grips the plates, and binds them harder together. Heading tools are used called snaps, these are held over the roughly formed rivet head and hammered while the opposite end of the rivet is held up to the face of the work by a lever; the snaps are an exact counterpart of the respective rivet heads.

In hydraulic riveting machines there is a snap on either side of the rivet, and when the work is ready in position a plunger is forced by the water pressure and a rivet head is thus silently formed to the desired shape; this kind of riveting is most effective; the pressure being so great that every part of the holes is filled and the rivet heads formed in perfect uniformity throughout the whole section. It is important that the rivet head is well home before the riveting by hand takes place, also that the stem of the rivet is of the right length for the work in hand.

STAMPING, OR DROP FORGING

Stamping is the forming of hot metal between an upper and a lower die. The stamping may be bent, formed, cut, and finished at one operation. The materials used are wrought iron, mild steel, aluminium, bronze, or copper. Usually the dies are in halves, unless it is that special projecting bosses or bends have to be provided for. The "setting out" and the construction of the dies have to be carefully considered so that the cooling metal as it contracts will leave the dies without any parts sticking. For this purpose, elevated portions have to be gradually toned down with suitable fillets, and bosses made with sweeping curves from the flats. The die patterns are constructed from drawings in the pattern shop, and afterwards moulded and cast in hard iron or mild steel. It will be obvious that with special care, the dies may be made sufficiently accurate as to need very little or no correction when they are cast and assembled. In fact, alteration of sunk dies would be a troublesome and costly task. Apart from this, the hard scale of the casting being also smooth lends itself to the process in a much better way than were the surface of the die to be tooled over, whether by hand or by machine tools. A finished forging is usually supplied, and the dies are as near as possible adapted to its contour. On examination the forging produced will show a thin fin left at the junction where the dies meet. This is, however, easily ground away at the emery wheel. Levers, lathe carriers, spanners, eye bolts, and numerous small parts are forged in this manner effecting a considerable reduction of cost in the production and in setting out and machining afterwards. A further modification of this principle has been produced in the forging machine which has a travelling bed not unlike that of a planing machine. One die, however, is a rigid fixture, and the other is carried at the end of the machine table. When the heated bar is placed in position, the table carrying the travelling die is fed towards the fixed die, the result being that the bar is instantly conformed to the particular shape of the dies, and the table recedes to be ready for the next bar. Some of the work thus bent is as much as 6 ft. long, and would take expert smiths a considerable time to produce.

NOTES ON CITY AND GUILDS OF LONDON INSTITUTE QUESTIONS

MECHANICAL ENGINEERING

SECTION "D".—FITTERS' AND TURNERS' WORK

Describe with sketches the marking off and the machining and turning of the central part of the crosshead.

The casting should be set on the lining out table so that a horizontal line can be scribed through the centre of the bearing for the gudgeon pin and also pass through the centre of taper hole for the piston rod end. Now the vertical line CD passes through the centre of the slipper and the gudgeon bearing, but not through the centre of the body, this being dimensioned 1½ in. and $1\frac{11}{16}$ in. respectively on each side of CD.

Therefore if 4½ in. is the total width at the small end or 2¼ in. above and below the centre line EF, and this represents the dimensions of the dovetail at EF, then the dimensions at 12 ins. from E would be 4½ in. + 1½ + 2 in. = 8 in.; but the length to be tooled is only $3\frac{3}{16}$ in. overall or ⅛ in. of taper per inch. The best plan is to erect perpendiculars LM, NO at 1½ in. on either side of CD and mark off 2¼ in. at M and 2⅝ in. at N and similarly at L and O respectively, also on the opposite side. These points must be carefully joined and lightly dotted in with a prick punch as guide lines for subsequent use. By scribing a vertical line at F the casting can now be turned over on its side and the line F must be set truly in the horizontal plane. Then by running a line all round the casting without disturbing the surface gauge point we can again use the prick punch and so complete the line work. Using compasses on the gudgeon pin bearing and on the mouth of the taper hole at F, circles can be now described and dotted in.

The setting out is most important in a crosshead especially in the adjustable type. Any slight error will be multiplied when it reaches the slippers and throw them out of alignment. This completes the marking out of the casting until more machining has been done, such as the cotter hole and the keyway shown in Fig. 7 (Fig. 216). It should be noted that this example in question must be tooled independently of the present system of interchangeability, and that there will not be the usual method of procedure, nor the use of special templets, gauges, or jigs, but simply the tools and gauges which might be found in any ordinary jobbing shop.

Parallel strips, such as may be obtained by cutting segments from a turned ring of metal, such as a piston ring, can be placed with advantage on the lathe face plate, and then by securing the crosshead to it directly by the gudgeon bearing surface it will be seen that the front face is entirely free of bolts and clips so that the centre finder or other indicator can be used without hindrance, thus effecting a saving in the time of setting. Three clips and bolts will be preferable to only two. By thus holding the crosshead an easy approximation of the centre can be made, and a balance weight fixed. This should be done by first liberating the front gear spindle wheel from the speed cone and then by careful adjustments the work can be finally set and verified after the balance has been satisfactorily obtained. Each nut can now be tested and, if necessary, further secured on to the clips. The bolts should be ⅝ in. diameter and as short as is practicable. Each nut should be preceded by a washer, and the nuts must rotate by hand or the clips may not get a fair grip. Another feature is not to have the clips supported too near to their respective bolts, *i.e.* the work being at a greater distance than the supports from the bolts. The latter gets more pressure than the former, and if not detected the pressure of the cutting tool will be sufficient to move the work out of its true position; especially is this found to be the case when the amount of metal to be removed is not uniformly distributed, also where a hard or soft place occurs, and finally, we always have this possibility of movement if the metal breaks off abruptly into a cavity or blow hole.

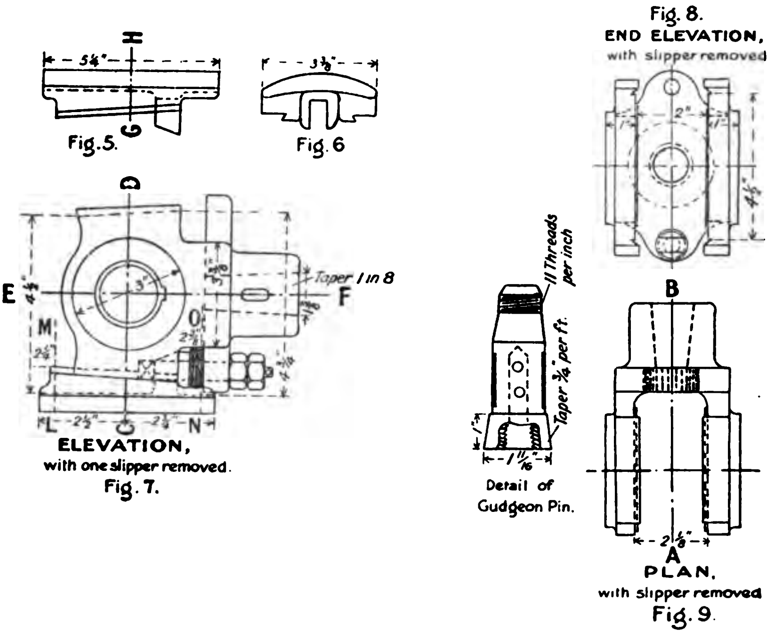


FIG. 216.—Steam engine crosshead.

It will be observed that the gudgeon pin is to be drawn up in position in the crosshead by a fine thread nut, the bearing portion of the pin being taper ¾ in. to 1 ft. or $\frac{1}{16}$ in. per inch.

Before boring the crosshead, the slide rest must be set to the above taper. This can be accomplished by placing a short but parallel shaft between the centres and scratching two fine rings at 4 in. apart round the circumference. Then set the swivel slide over approximately to ⅛ in. of taper in 4 in. A sharp pointed tool *fixed exactly on the centre line* can now be traversed between the two scratched rings, and when a strip of metal ⅛ in. thick is just held in tension, the pointed tool may be substituted by a boring tool *also fixed on the centre line* and the holes bored by hand traverse to the dimensions specified. The front face and both internal faces can be tooled at this setting, the crosshead being reversed for the remaining face to be tooled and finished. The boring tool should be as stout and short as possible. More accurate results will be obtained if the surfaces are tooled over first and the bearings roughly bored, then by means of sharp tools, the slide being slowly fed, while the speed of the work is run as high as is advisable for true cutting, the walls of the holes will be smooth and up to proper dimensions. By thus roughing out the work, the mouth of each hole will be more easily gauged when the finishing cuts are taken. This roughing out often proves useful in determining the quality of the casting. Should it prove defective, it may be destroyed and a sound one substituted before much labour has been expended.

The final lathe work will be to place a true angle plate on the lathe face plate, and on the inner table of the face plate secure the crosshead by one of the faces previously tooled. Referring to the drawing in Fig. 7 (Fig. 216), we notice that the line CD is at right angles to EF, therefore CD will be set parallel and EF verified by means of a true square, both from the lathe face plate. This will at the same time bring the taper hole at F into its true position.

This being done, the work is tightly clamped to the angle plate and is not again disturbed until the boring and facing have been completed. The bolts holding the angle plate to the lathe must now be eased a little and then, by means of a centre finder or other pointer, the dotted circle near F can be tooled as the lathe is rotated by hand or made to revolve at a very slow speed. A leaden mallet should be used to move the angle plate until the dotted circle near F is concentric with the lathe spindle. This being precise, the plate is firmly secured, a balance weight attached to the face plate, and the lathe started slowly and the setting finally looked over. Reference to the drawing shows the taper of this hole to be 1 in 8, or precisely twice as great an incline as the gudgeon pin bearing just finished. The distance of the zero marks can now be noted (if the slide rest is machine divided) or compassed with dividers and a further fine line scribed up to which the compound rest can easily be swivelled. The hole may now be roughed out and faced, and with a boring tool ground a little flat on the nose, the hole can be bored and finished to 1⅜ in. at the mouth.

Machining the Seating for the Slippers

There are two ways of doing this. The best is to mill the surfaces. Failing this they must be tooled on the shaping machine. In the former case the tools would be fixed previously. First an end mill made at 60° could be fed across the flat or upper surfaces, and next, by adjusting the height of the machine table, the Vee slide-ways tooled out to dimensions obtained preferably by a dial feed, or verified with a depth gauge previously set to the required distance. An end mill of 2¼ in. wide would cut out both Vees at once or singly if a cutter of less dimensions were used. An additional angle plate of similar proportions secured to the opposite side of the crosshead would be necessary if the work were tooled as described, but if shaped over and light cuts were taken, one plate only would be necessary. It should be mentioned that the inclined line at D will be brought into the horizontal plane and that the crosshead would be reversed on the plate for the opposite end to be tooled in a precisely similar manner to the first one.

By turning the work while thus held on angle plate, *i.e.* bringing the line EF into the vertical plane, the two holes at $4\frac{3}{4}$ in. centres can be drilled. We may now remove the work from that position and at the marking-out table place the line EF, and set out the keyway and the cotter hole respectively. The former will be cut out at a slotting machine, and the latter either slot drilled or by first drilling two $\frac{5}{16}$ in. holes, the extremes of which will be $\frac{7}{8}$ in. and afterwards, plugging up one hole and then drilling partly through the plug and partly through the remaining metal connecting the two $\frac{5}{16}$ in. holes previously drilled. The hole can be trimmed with a cotter file.

The slippers would be similarly marked, secured, tooled and fixed in the crosshead by their respective screws or studs. After the piston rod has been cottered home the whole is mounted in the lathe and the slippers turned and finished to 7 in. diameter.

TURNING AND SCREW-CUTTING A GUDGEON PIN FOR THE ABOVE CROSSHEAD

A short length of mild steel, $1\frac{3}{4}$ in. diameter by 5 in. long, can be centred and faced and turned to $1\frac{9}{16}$ in. diameter × 4 in. The opposite end may then be tooled to $1\frac{23}{32}$ in. diameter. Now the taper portions to fit the crosshead will, of course, be tooled with the slide rest swivelled to precisely the same position as for boring. When the largest diameter has been roughly taper-turned, fine rings can be traced with a pointed tool at 1 in., $2\frac{1}{16}$ in., and $\frac{15}{16}$ in. distance apart respectively.

Having done this, the diameter at the small end may next be turned parallel to $1\frac{1}{4}$ in. which is the size of the fine thread, and squared up with a knife tool to the mark of 4 in. from the large end of the pin.

The taper portions may now be turned down and the pin tried in the crosshead. By first chalking the surfaces, the points of contact will be more clearly seen when the pin has been rotated, and if correction is necessary, the slide must be eased in tension and moved with the mallet until perfect contact is obtained. The parallel part, viz. $1\frac{1}{2}$ in. diameter, can next be fitted to the connecting rod or standard gauge, and the pin polished up before screw-cutting.

SCREW-CUTTING THE PIN

The fine thread may next be screw-cut, viz. 11 threads per inch. The lathe guide screw being 4 threads per in. as stated, we have $\frac{4}{11}$ or $\frac{40}{110}$. The upper wheel is always a driver, and therefore must be placed on the spindle end of the lathe, while the 110, which is the following wheel, must be placed on the guide screw.

To connect these two wheels any suitable change wheel can be placed on the socket and the train made to rotate the guide screw by hand before the starting lever is touched.

Now, since 11 is not a multiple of the guide screw 4, the saddle of the lathe is necessarily brought up to a stop after each cut has been taken. The best stop in this case is the loose headstock. Before taking the first cut, the bolt is pulled by hand until the nut box lever will just drop the nut into gear with the guide screw. This being done, two chalk marks must be made, one on the guide screw and one on the face plate or front gear wheel. The above marks must be brought to precisely agree before each cut is taken, care being taken that the saddle is brought back before each cut and made to touch the loose headstock with the same amount of pressure. When the lathe is first started and a light cut is put on the work, the lathe can be stopped and a chalk mark made on the saddle screw and its bearing after the cut is spent. The slide is quickly withdrawn, the nut released, and the saddle run back.

A fresh cut can now be put ready by turning the saddle screw a little in advance of the previous mark, when a new mark is made, and then by pulling the belt the two marks, *i.e.* one on the guide screw and the other on the gear or on the face plate, are made to agree. The nut being lowered, the lathe can be started.

Now, the depth of a Vee thread of this description is shallow, that is, the screw-cutting tool must be carefully fed into the steel, so that the sides of the threads do not become jagged or torn. To prevent this, the slide should be free from end play, and the cutting tool, standing out from the lathe rest for as short a distance as is convenient, should be ground a little flat on the nose, but the angle must be 55° and set fair and square to the surface to be screw-cut. After a few traverses of the tool, the threads are finished by means of a hand chaser, an elbow rest being kept for this work. It has a smooth upper surface, and permits the tool to chase the screw. If such a tool were fixed in the tool box it would lie horizontally in a similar manner to the roughing-out tool, therefore the nearer it can be held in that position by hand the deeper the chasing tool teeth will be able to penetrate the screw.

When the tops of the threads are rounded off by the bottom of the chaser teeth the work is about complete, and no further pressure must be exerted on the chasing tool handle until the screw has been tried either in its own nut or in a hardened gauge nut.

The lubricant used is soap and water.

Question. Make the gauges shown in Fig. 217. The plug gauge is to fit the ring gauge.

Answer. There are several important points to be observed in preparing, tooling, and finishing the gauges. The plug can be centred and turned to $\frac{1}{32}$ in. over size, and the handle turned and finished by the use of hand tools with soap water as a lubricant. A bit of brass beneath the carrier screw and a strip of emery cloth wrapped round the handle will protect it from becoming bruised while in the lathe during the final tooling of the plug portion of the gauge.

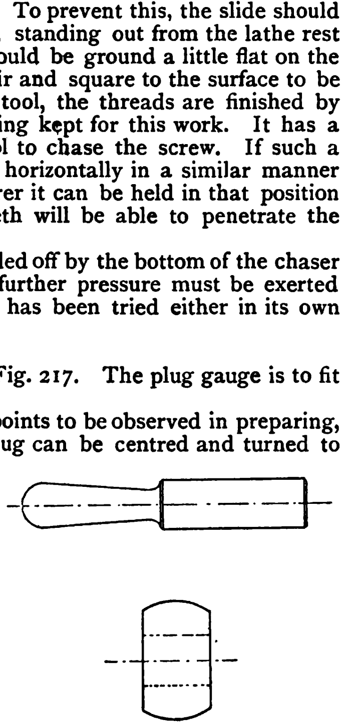


FIG. 217.—Cylindrical standard gauges.

It is presumed that the standard $\frac{3}{4}$ in. Whitworth gauges are in the shop for reference. To obtain the diameter and transfer the measurement correctly is most important. The outside calipers used should be broad at the points and held fairly and squarely to the gauge, passing over it only with a perceptible feel of touch. There is some experience necessary to know just when to stop tooling, and how to get a satisfactory finish on the work without overpolishing the surface. The work should revolve at a good speed, say 200 turns per minute, with a broad-nosed tool traversing at about 40 turns per inch, then, with a good supply of lubricant, the surface can be made comparatively smooth, and the dimensions should leave nothing for filing, but just a little to be removed by polishing. This small reduction must not be attempted by hand finishing, *i.e.* by simply holding a strip of emery cloth between the fingers and sliding it backward and forward as would be allowable on a less important object. A small pair of polishing clams with a copper lining and a sprinkling of crocus powder will quickly make the reduction. Failing the copper clams, a small piece of hard wood sawn to fit over the hand rest, with a narrow strip of "O" or "OO" emery cloth fastened to fit it, can be fed along the work by means of the slide rest. There will be a certain amount of heat produced and consequent expansion due to the polishing. This must be cooled, and gauging only done when the work is at the normal temperature of the workshop. The use of a micrometer would quickly indicate any elevations and show some of the hollows on a piece of work, especially after filing and hand polishing, or even used as a gauge to test or compare with the Whitworth standard. It is a superior instrument to the ordinary calipers, inasmuch as it indicates the amount of inaccuracy either above or below the actual standard size.

Before leaving the finishing, it should be pointed out that all polishing materials must be kept on the move over the surface to be polished. There is a tendency for the near end of a piece of work to receive more than its share of attention, and in the backward and forward motion the central part of a short piece of work may also become somewhat hollowed. From this it will be gathered that for such work of importance it is essential for precise measurement to be both obtained and transferred, and a smooth cutting tool evenly fed on the surface of the gauge if the subsequent polishing is to be reduced to a minimum. In the "City and Guild's" question no mention is made of hardening or grinding the gauges, but in all shops manufacturing gauges for the trade a margin is left to be reduced by grinding after hardening.

The gauge is mounted on centres in a special grinding machine, and a fine carborundum or alundum wheel is automatically fed along the surface of the gauge; this wheel revolves at a high peripheral speed, and is exceedingly sharp cutting. In this respect it is much superior to the very best steel turning tools, since the wheel is capable of making a reduction so minute as to be immeasurable. A further advantage is that there is no polishing necessary on hardened steel properly ground. In the tooling of the ring gauge, the forging must be mounted in a chuck and bored a little below size, and then faced up. After removal the ring can be turned and finished on a mandrel to dimensions required. A final setting must be effected in the chuck and the hole made to standard size with a tool well oilstoned and lubricated. This will obviously require the most careful handling of the calipers if precise results are to be obtained; that being so, a fluted reamer should be used, in preference, for finishing; then, if the reamer is in good condition and of standard size, the work should be correct.

Now, well finished external and internal gauges, representing ¾ in. must necessarily only have an extremely small amount of difference in their respective diameters; so small is this that they will "seize" if the plug is inserted in the ring whilst dry, but when a coating of grease is applied they will slide easily. To obtain this high degree of accuracy in these fitting parts, must be the work of an expert, and can scarcely be expected from any one else. There is, however, the possibility of lapping out a bored hole until some approximations of the desired standard of fitting is obtained. A lead or copper lap turned to slide through the ring, with a smearing of crocus powder and a film of oil on the surface will remove any irregularities in the ring's bore, and enlarge its diameter. The ring must be slid and rotated steadily and evenly along the surface of the lap, and not allowed to heat, while the lathe is rotated at a high speed. Each time the gauge is removed from the lap it must be thoroughly cleaned before any attempt is made in testing the actual diameter. A lead or copper lap should be a little shorter than the surface to be lapped, this gives an opportunity to lap or grind out a local part without the entire surface being in contact, or the ends of the lap reduced in diameter a little. There is a considerable amount of skill necessary to make a hole parallel, concentric, and to a precise diameter throughout.

The "charging" of a lap is to increase its diameter by adding a thin layer of flour emery or crocus powder; this should be pressed into the surface by a roller so that the truth and diameter of the lap shall be kept uniformly correct.

It must always be remembered that while the surfaces are in contact there will always be a cutting action, not only at the part we desire to grind, but, unfortunately, at other parts too.

The cutting or abrading action can be minimised by removing all traces of emery and oil from the lap, and after careful gauging to find the precise position where the diameter of the bore is the smallest. Then an attempt should be made to grind that portion only. A faint smear of emery and oil should be put on the lap, and the latter inserted in the bore of the piece to a measured distance before the lathe is started, then, with a few revolutions and the work just slid backwards and forwards, the lap may again be withdrawn and the diameter minutely tested as before until it is parallel.

With an accurate grinding machine, however, the above difficulties do not occur, the machine slides perfectly parallel, and there is, therefore, only the precise diameter of the standard to copy and transfer.

MANUAL METAL WORK

Question. Forge and otherwise prepare and finish for use a centre punch of the form and to the dimensions given in the sketch (Fig. 218).

Answer. Cast steel must be very slowly and, thereby, thoroughly heated to a dull red before any hammering whatever is done. Eight flats are to be made extending for 2¼ in. These should be produced by first obtaining four faces of a uniform width, but before the corners are in any case allowed to grow sharp, the second four are formed. In commencing this work, it may be mentioned that as the upper face is fairly and evenly struck, there will be a corresponding flat surface produced by the hot steel in contact with the hard face of the anvil. The work then must be given half a turn occasionally so that the facets made shall be equally wide. Next a quarter turn, and the process, being repeated, should leave four facets with a curved portion still left between each. A fresh heat will now be required to reduce these remaining faces to dimensions, and for this work a short but rather heavy hammer is to be preferred to a long-shafted light one, since it takes a considerably heavier blow to forge cast steel, than is required for mild steel or wrought iron.

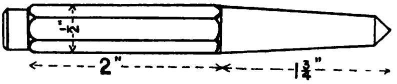


FIG. 218.—Making a centre punch.

"Hollow bit" tongs should be used and a "collar" put on the "reins" to hold the steel uniformly square to the anvil face. Everything depends upon the suitability of the tongs and hammer, and of the force and straightness of the hammering in this kind of work, in fact, if these are not attended to properly the steel may soon be spoilt, and become a source of danger if it "flies" out of the tongs.

A further heat, and then with the steel tilted a little the head may be formed, leaving a little for filing. The opposite end can now be heated and drawn down, tapering; meanwhile the tongs should be rotated gradually, so as to keep the work straight, and evenly drawn from each facet. There must be rapid hammering since the section is a small one, or the steel will quickly lose its heat and plasticity.

As the punch nears completion the hammering becomes more rapid, but with less force, and finally the work must be re-heated, cut to length and roughly pointed. After forging, the flats are filed up in the vice, copper or brass clams being used to protect the finished surfaces. By gripping two faces the two opposite ones may be filed, then the two finished faces are gripped and the liberated ones filed up. This will of course leave a facet between each of the filed ones, and in dressing these the width of each must be judiciously watched, and frequently gauged over. The sliding caliper gauge and the bevel gauge should be used. The former set at $\frac{33}{64}$ in. and the latter at an angle of 180°.

MANUAL TRAINING EXAMS.

Question. From the given piece of mild steel plate, construct a try square to the given dimensions. The stock to be built up and riveted together as shown (Fig. 219).

Answer. The tools necessary for the work will be a hammer and chisel to cut up the stock, a 10 in. or 12 in. second cut file, an 8 in. or 6 in. flat with one safe edge, a 4 in. flat, smooth, with safe edge, and a short scraper. Appliances; chipping block, oil-can, No. 1 emery cloth, polishing stick, surface plate, and vice with lead, copper on brass clams, filing board with cramps and ochre for marking.

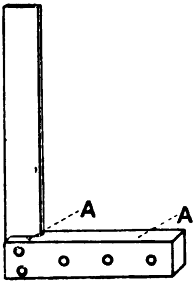


FIG. 219.—Built up try square.

Marking and gauging tools, steel rule, sliding caliper gauge or micrometers, true try square, scriber and centre punch, also a flat strip of steel truly scraped on one surface and made with a slit at one end to pass over the square blade (Fig. 219A.) (this plate is used to test the upper surface of the stock, including the sides near the blade). There are two ways of cutting the plate; first, the three pieces may be scribed out and chipped, leaving a margin for filing up; second, the three pieces may be set off for drilling away the surplus metal. In point of time the first method is considerably the quicker. There is always, however, the danger of cutting too near to, or over, the line, also the metal generally alters its shape during the process, and, of course, has to be re-set or straightened. By the second method lines may be described allowing a small margin all round the pieces for filing up. Then at a uniform distance from these lines a second set of lines may be made parallel to them, then, at uniform distances apart, centres for small holes may be made, and in this way the surplus metal drilled out. There will be more filing necessary, but the bending of the plate will be considerably less than by the former method. The pieces should be cut out, trimmed with a file on the edges, and roughly ground up to remove the scale; it will, however, be subsequently necessary to make each face precisely flat, so that when assembled and riveted together the joining will be scarcely, if at all, visible.

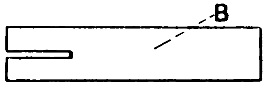


FIG. 219A.—Gauge to test surface A.

B.—MECHANICAL ENGINEERING—WORKSHOP PRACTICE.

HONOURS GRADE. TURNERS' WORK

Question. A forging is supplied. Turn a small crank to the dimensions shown in Fig. 220, "Setting Out."

Answer. On a pair of Vee blocks placed under A and B lay the forging and set the sides FG to stand vertically, chalk or whiten the parts to be set out. With the surface gauge draw a line through the mean of AB on both sides of the forging also on the ends CD. Measure the height of the finger point and then raise it $1\frac{5}{8}$ in. for the crank pin, make this line definite on both sides and ends of CD. Now give the forging a thorough overhaul, *i.e.* in this case see that there is sufficient material for turning the crank by carefully looking above and below the centre lines.

If this is quite satisfactory the crank is given a quarter turn, and this is most important; the horizontal lines at the ends HI will be now vertical. The same applies to the lines CD. With the surface gauge set approximately to the centre a line is scribed all round the forging, *i.e.* both ends and sides. The forging being given half a turn the lines just drawn can be verified by means of the surface gauge, and if correct the lines may be dotted with a fine-pointed prick punch.

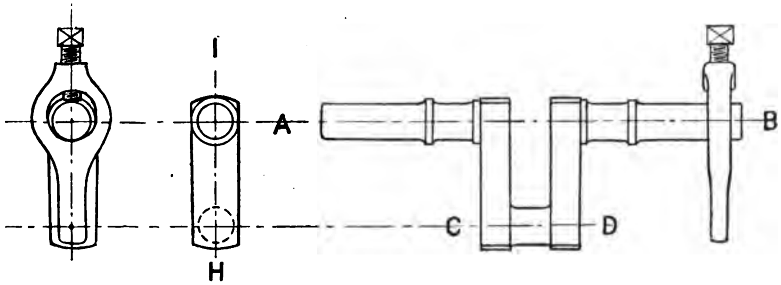


FIG. 220.—Setting out and turning a small crank shaft.

Remove the work to the vice, and with a finely pointed pair of compasses draw a circle, say 1 in. diameter, on each end of the part AB and dot in the centre a little deeper using alternately a larger and smaller pointed punch until the hole is deep enough to be drilled without fear of moving in position. The compasses will quickly show if the centre attempts to wander, and a few blows properly directed will be sufficient to correct it. This work cannot be square centred owing to the weight of the crank being for the most part on one side of the centre, the hole must be enlarged by means of a breast drill, or other hand drilling appliance.

In turning up the crank shaft bearings it would be the wisest plan to rough out the shaft all over with $\frac{1}{32}$ in. left for finishing. A carrier fixed on each end of the shaft can be used to receive the centres for the throw instead of crank blocks, as is the case when quantities of similar shafts have to be turned.

To obtain the true centres for the crank the shaft is again laid on Vee blocks and the markings previously obtained transferred by means of the surface gauge to the carriers. Unless the carrier is provided with a round hole the centre could not be struck, the reason being that $1\frac{1}{32}$ in. diameter shaft leaves a very small margin for the centre for the crank when the actual distance between the radii is only $1\frac{5}{8}$ in. or a little less than $1\frac{1}{8}$ in. between the rim of the shaft and the centre proper of the crank. Considering the dimensions of the shaft to be turned, the centre hole will, if made as above, be large enough ; if, however, the carrier bore has a V-shaped root, then a strip of mild steel bent at a right angle, and long enough to reach the web of the crank when it is fixed beneath the work by its long arm, will answer quite satisfactorily if the centre is marked off and made in the short arm. Of course this is understood to represent only a temporary device, and not one which would be adopted where duplicates are frequently required.

It may be noted that crank blocks are provided which fit the shaft and are further secured by one or two set-screws to prevent any possibility of movement. After the holes have been deepened the crank is mounted between the centres and the throw carefully turned and finally finished to gauge size with a spring tool. This being completed the work is polished up and the drivers removed. The widths between the webs must be uniformly maintained.

B.—WORKSHOP PRACTICE. (A) FITTERS' WORK

Question. Make the sliding calipers shown in Figs. 1, 2, and 3 (Fig. 221). The part A is to be riveted to the part B. B is to be filed out of the solid.

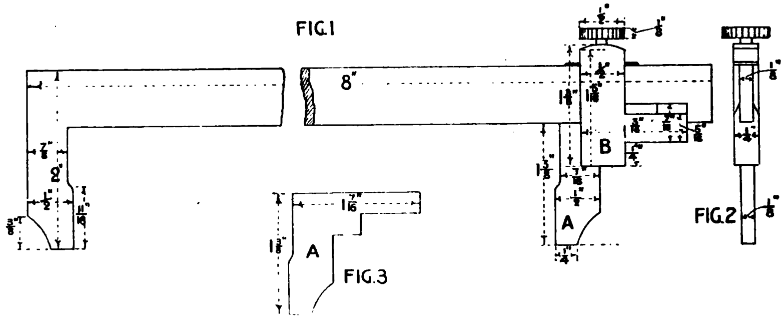


FIG. 221.—Sliding caliper gauge.

Answer. The various parts are to be built up so as to form a sliding caliper gauge. Having tested the pieces and proved that they will hold up to the drawing dimensions satisfactorily, the bar can be ground on both sides and the straight edges filed in a preparatory way. The dimensions, $\frac{5}{8}$ in. × 8 in. × $\frac{1}{8}$ in. thick, can be decided by means of a sliding caliper gauge and a steel rule. In removing the sliding jaw the instrument is converted into a suitable try square.

A filing board or block, or failing this a parallel strip, can be used on to the surface of which the bar of the caliper may be clamped. Should the material be bent originally, or after it is roughly filed, it must now be "set" by light hammering on a true bench block until *one side* is practically flat, and this side (X) being clamped down should prevent further trouble in this respect.

This piece may be finished by draw filing each face and edge, using a smooth 4 in. or 5 in. flat file, taking care to prevent the file "pinning" by filling the teeth with chalk. A little oil on the work will improve the surface, but all the teeth must occasionally be cleaned before they get clogged, and a fresh start made.

It is important to observe the following points in this relation, and the use of the following instruments to gauge the progress of the work. A sliding caliper gauge, a steel rule, straight edge, square, failing the sliding caliper gauge or micrometer, reliable calipers must be used as a substitute.

In most shops an emery or corundum wheel is now used in place of grindstones for roughly dressing forgings, etc., also for glazing and polishing finished surfaces. The work in hand, however, must not be *finished* or polished other than by *handwork* at the vice, or the flats and edges of the bar will be destroyed. The piece A, Fig. 3 (Fig. 221), can be filed up to shape, and a little over finished sizes, but the top side $\frac{7}{16}$ in. long, must be flat and true at right angles to the shoulders, also to the side edge marked $1\frac{3}{8}$ in. long. Small files of 8 in. to 4 in. long do better work than the long ones, especially in the hands of students and apprentices who have not had sufficient experience to enable them to file a small surface straight with a large file; indeed it is practically impossible to wield a long file evenly across a narrow surface.

Now the sliding jaw A is $\frac{1}{8}$ in. thick, and has to fit in the part B, and is there secured by rivets, but the caliper arm on which the parts B and A slide together is also $\frac{1}{8}$ in. thick. Therefore the marking out and subsequent filing of the slot in B is most important, and will need very great care to keep the slot straight and true. A slit down the centre of the edge of B with a new hack saw, and the extremes levelled to a little below $\frac{1}{8}$ in. should help matters considerably. The piece should be examined frequently to see the progress of the work on all parts, so that any necessary corrections can be made as the opening nears completion. The depth of this slot is $1\frac{1}{8}$ in. × $1\frac{3}{8}$ in. at its greatest width. The most suitable files for the purpose are small ward or slitting files, and parallel slotting files. Before the piece B can be properly fitted the arm should be smeared with red ochre, so that marks will be discerned showing the points of contact; these should be carefully removed and the part B again tried. No hammering or forcing must be attempted or the mouth of the slot will be enlarged above size required.

MECHANICAL ENGINEERING

Question. What is the object of "chipping strips"? Make a sketch of an ordinary pedestal and describe the fitting of the brasses into the body and cap. Also describe the boring of the brasses and the arrangement of the oil grooves.

Answer. 1. Chipping strips are put on the edges of a surface to reduce surface contact; generally they are put on the base of brackets, blocks, pedestals, etc., to be chipped over when the brackets, blocks, or pedestals are assembled in their respective places. It is customary to tool over surfaces of brackets, pedestals, etc., when the seating on which they rest has also been machined. In many cases the seatings are only trimmed by hand, and it is not unfrequent to see such a seating decidedly out of truth with the alignment of the shaft or shaft bearing a little distance away.

It is therefore obvious that the only way to accommodate the shaft is to adapt the base of the pedestal to the seating out of truth. This may necessitate the removal of the chipping strip at some points on the surface, but there is no other way but to adapt the two by chipping the base of the pedestal and finish it by filing until the shaft will revolve freely when the pedestal is finally screwed home.

2. There are two distinct methods by which the brasses may be fitted to the body and cap. First, the brasses for important work. These are faced at the joints and either sweated (soldered) together while they are bored

and turned, or held in a pair of clips during the tooling operations at the lathe (Fig. 222). The pedestal is bored and faced to receive the brasses. Second, a less important method is to cast the upper and the lower brasses a little less between the shoulders than the width of the pedestal, also to use a pattern shaped to hexagonal or octagonal form, and the faces are trimmed with a file until there is coincidence between the lower brass and the pedestal, and the upper brass is adapted to the cap in a similar manner. The time spent in adapting these parts is greater or less according to the requirement of the work in hand or custom of the shop management.

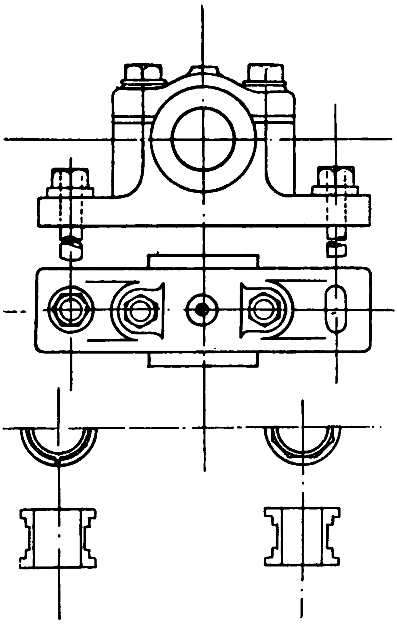


FIG. 222.—Pedestal bearing and brasses.

The oil grooves are cut with a round-nosed chisel branching from the oil-hole in the upper brass. In the lower brass a similar cross groove is cut, but, to retain the oil, the grooves terminate before they reach the edges of the brass.

MANUAL TRAINING—METAL WORK

Question. How would you proceed to repair the following breakdowns or damage which could at any time occur in a metal-work centre?—

(*a*) A leather link belt (gas engine to main shaft drive).

(*b*) The cast-iron nut of a square thread vice screw, which has fractured and fallen away in one piece, leaving the other portion intact with the screw in position. A new one is not possible, or the vice removable, for the time being.

(*c*) A broken chipping chisel.

(*d*) A broken twist drill.

Answer (*a*). A stout pair of flat clips are fitted on the open ends of the belt and then secured. A pair of hand vices is then used to withdraw any defective rivet, the riveted portion being removed with a small triangular or half-round file. A little oil on the pin will make it pass through the leather links easier (Fig. 222A).

To repair the belt a new rivet is slightly pointed and gripped in the hand vice by its head. Before inserting it the belt should be tied where there is most sag, and, if practicable, supported there to carry the weight. The links can now be threaded in place and the rivet carefully turned through the belt holes as though it were a screw. It is of no use hammering the rivet; the friction is too great for it to pass. It may be found that when a little progress has been made the pin sticks; this can generally be remedied by fixing the links in position as the point of the pin proceeds. The pin must not be unduly forced, or it will bend and be useless. A good plan is to insert a long wire slightly less in diameter and pass the rivet as the wire is gradually withdrawn. When once in, the head must be supported on a flat surface such as the face of a stout hammer, and then a zinc or copper washer can be mounted. Before attempting to secure the rivet a punch having a small hole should be used first; the washer will be forced down and the links will be slightly compressed, leaving enough of the pin standing for riveting (not more than $\frac{1}{8}$ in.).

By still supporting the head and giving very light blows the rivet will form a new head and so be completed.

In very wide and heavy belts two pairs of clips are used with the ends of the belts between them. They are then drawn together by stout bolts and nuts. This system is effective for the widest of belts, both to hold them taut and straight and to stretch them before taking up the slack.

Answer (*b*). Note that the broken vice screw nut has a portion still intact, and that the piece which has fallen off must be less than half the diameter of the whole.

A simple temporary "rig up" is to fix a collar having a set-screw to hold the two parts together. Another plan is to bind the parts fast together with copper wire and secure this with solder. If strong enough to stand, rivets can be inserted.

Answer (*c*). The burnt chipping chisel can be restored by carefully heating it and dipping the end in a mixture of carboniferous powder specially prepared for the purpose; failing this, cut off $\frac{1}{2}$ in. and draw out anew and retemper to a tarnished copper colour. Finish by grinding the sides parallel, the facets true and slightly curved on the ends.

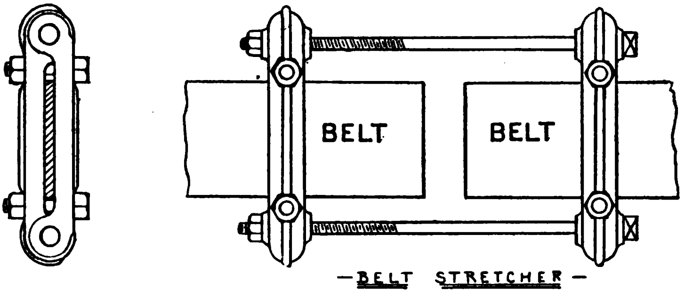


FIG. 222A.

Answer (*d*). The broken twist drill must be heated, a small portion cut off, and the end "upset" to thicken before "spreading." It is assumed the drill to be hand forged. An ordinary machine-made twist drill will only need regrinding, preferably on a twist-drill grinding appliance.

The pointer nose of the drill should be pointing towards the crown of the fire, or even laid outside on the top of it to get the stem hot; the heat will quickly reach the end. In forming the facets the drill should be laid on the beak or horn of the anvil with the shank and tongs towards the floor and struck lightly, alternating the position of the work so that a V point is formed. After this the drill is straightened, hardened, and tempered to a very dark straw or pale orange colour. In grinding, the facets should be held at one inclination until the point is central; the sides should gradually taper inwards as they recede.

Question. The adjustments of a simple traversing lathe are all faulty, resulting in non-parallelism, chattering, hot bearings, and dragging in of the cutting tools. Enumerate these faults as A, B, C, D, and suggest probable causes of each defect, and the most effective repair you would adopt to produce an efficient tool. (A new lathe is out of the question.)

Answer A indicates that the saddle does not fit properly to the "ways" or "shears" of the bed at all points along its traverse, also that the axial alignment of the loose headstock centre with the centre of the fast headstock has become defective through wear.

B shows that the various strips to the slides are loose, or if let up to their full capacity, are binding on their upper surface instead of on their angular face.

C. There may be several causes for these, such as irregular wear in the bearings, or more wear on the front neck of the driving spindle than at the back or end one.

In journal bearings the front one drops out of alignment through excessive loads, *i.e.* large face plates carrying heavy work. This fault is frequent.

D. Digging or dragging of the cutting tool is from the same cause as B, or that the poppet is worn, and its bearing in the loose headstock enlarged. If the cutting tool is unevenly secured in its seating on the lathe-rest there will be a tendency to drag or dip into the work.

The reader will note that the question requires "The most effective repairs to produce an efficient tool."

The whole lathe, therefore, must be stripped and each working part thoroughly overhauled, new parts being furnished if necessary. Commencing with the bed, a trammel or caliper must be used to test the actual width at various intervals along its length. The width at the widest part must be compared with that which has had the most wear; the upper surface tested both in a longitudinal and transverse direction. It may be that the surfaces can be corrected with a good filing and final scraping to a surface plate. If the surfaces are too much worn, the bed must be fixed on a planing machine or on a milling machine and lightly tooled over. The setting is very important in this matter, since there is but a very small amount to be tooled off. The scraping would follow as above.

The saddle being now laid on the bed, will be tested, also the Vee for parallelism. This may be scraped to fit properly to the bed if but a little error is found, or it may need tooling in a similar manner to the last example, and subsequently adapted by scraping. A new saddle strip must then be fitted and secured. The next is the transverse slide "ways." These will be found to have worn hollow, but as the surfaces in contact are of less area and shorter compared with the saddle and bed, machining will not be necessary, say, for a lathe of 6 in. or 7 in. centres. Above these sizes tooling would be first resorted to. The tool rest, or as it is called, the compound rest, will be filed, scraped, and padded, then fitted with a new strip, and this part of the work is finished by adjustment.

The spindle in the fast headstock, if provided with conical necks, may be turned up on the cones, but a hardened spindle can only be fitted by grinding. The phosphor bronze bushes must be withdrawn and chucked and re-bored, or ground if of hard steel. The adapting of these bearings to their counterpart on the spindle is most important work, for on the accuracy of these depends the sweet running of the lathe. The key on the spindle for the front gear wheel can be tested if a tight fit, otherwise a new key must be substituted.

All gear wheels and racks must be examined, and broken teeth cut out and new ones dovetailed in, then passed through a gear-cutting machine. The speed cone, too, if worn, must be re-bored and bushed, then lapped out to fit the spindle. The back gear is generally inserted or removed by means of an eccentric shaft. This must be tested in its bearings, and if at all shaky new bushes made and fitted. The key may also need renewing, since other vital parts are faulty. The saddle screw and rest screw should be carefully examined by looking at the thickness of the threads. If thicker in some parts a cut may be put down to equalise them. This must not be considered as a wise or economical course to adopt, and only in cases of a comparatively small amount of wear is it admissible; badly worn screws must be substituted by new ones. It may be that the nuts in the saddle and rest-screw slides are very much worn. A cheap way is to cast these nuts in place on the respective screws, but such nuts are not easily fixed, because there is usually a nug cast on each, which must be turned to fit the slide which carries it. There will therefore necessarily be required the greatest possible care in locating the true position of the centres for this nug, because of the square thread already being within the nut.

To do this effectively the slides must be set evenly horizontal on the edge of the Vee and true to a try square and with a surface gauge, the centre of the screw bearings obtained and transferred to the seating for the nut. This will indicate the actual position for the centre of the nug, and also show at once whether the drilled hole is quite concentric with the marking so obtained. If this is not coincident the precise amount of error must be given to the centring of the nut, relative to the axial alignment of the screw and its bearings. To obtain the exact distance from the nut seating on the slide to the tops of the screw threads is also imperative. A line must be scribed on the nut to this amount, and the surplus metal tooled off when the nug is turned up. It will therefore be gathered that "casting" the nut in the above manner is very troublesome to subsequently get in place correctly, and for that reason, and the fact that cast screw threads are not so good as cut ones make it advisable to avoid the process for such particular work. In actual practice new nuts are turned, fitted, and then marked out directly from the screw bearings, and without again removing them the slide is secured in the lathe, and "set" precisely to the marking on the nut, the latter being then bored and cut to fit the saddle screw. This is a sure method of procedure to obtain a nut precisely in line with the screw bearings. It may be pointed out that both the saddle and tool slide nuts could be fitted in their respective slides and bored and tapped without removal. This method is considerably quicker than the above, since tapping is sooner accomplished than re-setting the work and screw-cutting the nuts. Whatever is done, there is nothing to compare with a nut properly cut from a master screw in the lathe. By constant sliding up and down the bed to admit various lengths of work, the "loose head" base will have worn, and therefore dropped out of true alignment with the fast headstock. To test whether this drop is even the head should be secured, and the poppet wound out over two-thirds of its full length. A scribing block will show if the wear has been evenly distributed, and if not this can be corrected by filing and scraping the surface. The headstock may now be secured in place on the lathe bed and the height of poppet compared with height of spindle in fast headstock.

Now the heads must be inverted and set by their respective spindles on the bed of a planing or milling machine, that is to say, the two headstocks must be secured, and the axis of both spindles set in true alignment, and the fast headstock base tooled over until it is of a corresponding height with the loose headstock, or it may prove desirable to run a light cut across both surfaces, and finish by hand scraping. It will be assumed that the fast head is provided with means for taper turning, so that should the lugs in the loose head need re-facing, they may now be tooled over sufficiently to allow a thin strip of metal to be subsequently put on and riveted to each lug.

In the case where the fast head is bolted down with fitting bolts to the bed a more careful handling of the loose head will be necessary. A vertical line must be drawn at each end of the headstock, precisely through the centre of the bore, then with a pair of compasses an arc may be described, showing the amount actually to be tooled off the respective sides. The accuracy of this tooling is most important, as parallel turning is impossible unless this work is correctly done.

DRILLING TWO HOLES AT 60° CROSSING EACH OTHER

Question. Two holes, crossing each other at 60°, and with the axes truly in the same plane, are to be bored through a cast-iron block with an ordinary drill (a twist drill is not available). Write down the procedure you would adopt to ensure that the axes were in the same plane and to secure a satisfactory job. Give pictorial sketches to demonstrate your method clearly.

Answer. An angle plate must first be secured to the table of the drilling machine, with the work set sufficiently forward to give full room for the drill to clear, or elevated on packings. Now there is no mention of the precise shape of the block, so for our purpose we have chosen a rectangular block with two corners suitably cut, that the drill may have a correct start. In setting out the work we shall first draw AB through the centre S of the body of the block, and CD and EF must then be drawn crossing each other at S. Then at right angles to CD let GH be drawn through the point S, and similarly LM at right angles to EF may be drawn through the point S.

Therefore the line CD will be in the vertical plane when GH is parallel with the machine bed, and in like manner EF will be in the vertical plane when the line LM is made parallel with the machine bed.

To guarantee that the two holes shall be bored in the same plane, there are two things essential. The angle plate supporting the work should move in a line precisely parallel with the drilling machine spindle. This may be accomplished by doing the work at a radial drilling machine, having a swivelling angle plate about a fixed point. Failing this, a temporary one may be made by securing two plates together and moving the one carrying the work about an axis, say, of a turned and fitted bolt. Secured in this way the position of the drilling-machine spindle, after having been properly located for one hole, must not be disturbed until the second hole is finished.

It will now be obvious that a flat drill of the ordinary type cannot be controlled sufficiently to make the second hole straight at that part where the first hole has crossed its path. (In this respect it is unlike a turned twist drill which is guided onwards by the drill filling the walls of the hole at all points of its circumference for a considerable distance of its length.) Therefore immediately the first hole has been bored, a short plug of turned cast iron should be driven into the hole. By this means the second hole will be drilled through solid metal, and thus two holes, crossing each other at 60°, and with the axes truly in the same plane, may be drilled (Fig. 223).

NOTE.—The above question is severe because an ordinary flat forged drill is prescribed. If a parallel drill were allowed it might be possible to drill the holes even without a plug. In this case the parallel drill actually does the work better than the twist drill, since it fills the hole more perfectly at every point.

MECHANICAL ENGINEERING—FITTERS' AND TURNERS' WORK.

Question. Describe the marking off, and the turning of the steam stop valve.

Answer. The brass steam stop valve casting is to be faced truly at the faces XY and M respectively, also to bore at X for the cover, and at the opposite end a hole 5 in. diameter for the valve, and all at the same setting to chamfer the inner edge for the valve seating (Fig. 224).

The flange faces and the boring can be tooled in several different ways. It may be secured to the table of a vertical boring mill and there bored, and one face tooled simultaneously, or the casting may be secured by the flange M to the table of a "pipe facing and boring machine" and the faces X and Y tooled together; then at the same setting the boring can be done. Angle plates secured to the tooled faces X and Y leave the face M ready for the final operation, on the same machine. A further method is to do the work entirely at the lathe by securing the valve by the flange and facing and boring as required; each flange being tooled in turn.

Referring to the sectional elevation it will be seen that the valve cover fits into a bored hole by a small shoulder and that the upright, and in every other respect true position of the valve spindle depends upon the fitting of the cover to the body casting. The cover will be faced and bored $1\frac{1}{4}$ in. to fit the spindle and 2 in. diameter at the mouth for the gland. After tooling the flange is "let in," and secured by cramps while the ten stud holes are drilled to $\frac{5}{8}$ in. tapping size. The drill may now be substituted for a $\frac{5}{8}$ in. one and two opposite holes opened in the cover, and then tapped $\frac{5}{8}$ in. standard into the valve flange beneath. By holding the cover in this way each tapped hole being fitted with a short screw, the remaining holes may now be drilled partly through and the cover removed for finishing. The holes, however, will be true and straight, although the flange is but $\frac{11}{16}$ in. thick.

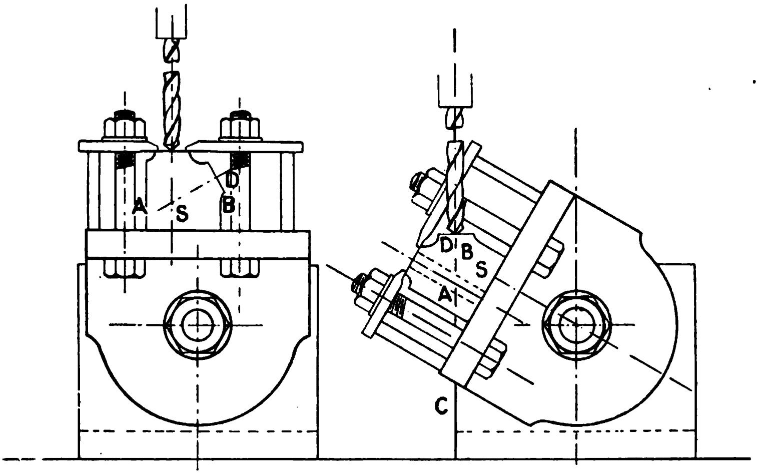
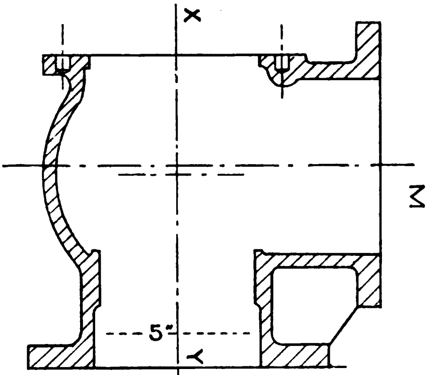


FIG. 223.—Boring holes at 60°.

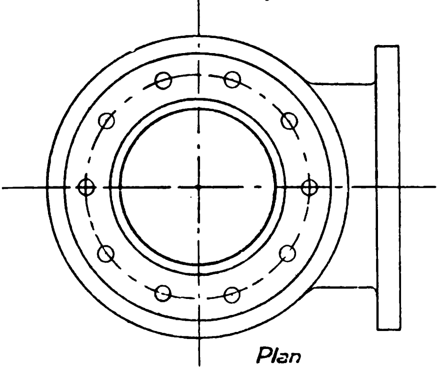
It may be pointed out that brass is a difficult metal to drill, after a hole has been made, and it is decided to enlarge it, *i.e.* the less there is to be removed, the more the tendency for the drill to refuse to cut evenly.

For the above reason some prefer to use a drill full size and allow the point of the drill to make a good impression on the surface which is to be drilled subsequently tapping size. Whichever plan is adopted, the cover can be made a first-class job by having it "assembled" while the taps are operating on the valve flange beneath; this is almost essential, since the depth of the hole to be threaded is very shallow.

Where quantities of similar pieces are tooled the appliances and gauging would be different to those employed for single or but few valves. It is the custom to dispense as far as is practicable with marking out, and to adopt jigs wherever it is conceived to be practicable. A jig on the surface of the valve cover would be employed during the drilling processes, and on its removal a $\frac{5}{8}$-inch tap would be inserted in the drilling machine special socket, and each hole tapped and the studs inserted without removing the valve in any way.



Section of Valve Body



Plan

FIG. 224.—Marking out steam stop valve.

This latter practice obtains in large works, and thereby not only increases the output considerably, but clearly shows that manual labour for such work is growing less.

(a) FITTERS' WORK. MECHANICAL ENGINEERING HONOURS.

Question. Four small castings and four set screws are supplied to you. Finish the castings to the dimensions shown in Fig. 225, and fit up so that the slide A shall move smoothly but without any shake. A good job is required.

Answer. This is a piece of work requiring very great care in setting out and in machining, also in erection afterwards. There is only one moving part, viz. the inverted T slide A which is required to be a smooth working fit (Fig. 225).

The castings supported evenly on the marking-out table should be scribed out, commencing with the base, above which a horizontal line a full $\frac{1}{16}$ in. should be drawn, a second line at $\frac{3}{8}$ in., and another at $\frac{1}{2}$ in. above it, and the casting being similarly treated at the opposite end completes the work for this setting. The casting should now be turned over to bring the lines into the vertical plane, these must be carefully verified at both ends with a true "try" square. The mean centre of the casting can now be found, and the extreme lines at $1\frac{1}{4}$ in. above and below it will give the $2\frac{1}{2}$ in. over all dimensions which the casting should be after tooling up and finishing.

Lines at $\frac{5}{8}$ in. on either side of the centre line give the width of the recess for the reception of the slide A. The two strips C may now be marked, viz. to finish $3\frac{1}{2}$ in. long, 1 in. broad, and $\frac{1}{2}$ in. thick respectively.

Now, there are two important factors in this problem, viz. precise measurement and accurate tooling. It is therefore assumed that the student has free acess to gauging instruments, and that he can appreciate their several uses.

In setting out the slide A with its seven surfaces, it will be observed that six of these are in direct contact with surfaces on B or C, while the remaining surface must be in perfect alignment with the upper faces of the two strips C.

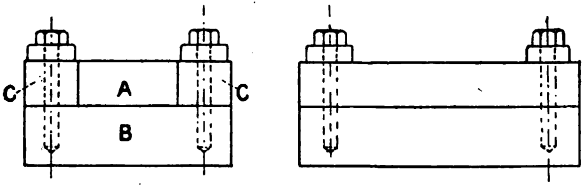


FIG. 225.—Fitting four small castings.

In commencing the tooling, the upper part of the casting B should be secured to the table of a milling machine, preferably of the vertical type, while the flat surface or base of the casting and the two sides are tooled up with "end mills." In this setting the casting will be made smooth, with a flat surface $2\frac{1}{2}$ in. wide precisely to the gauge. An end mill would also tool the end at the same setting by shifting the position of the clips. Tooled in a horizontal milling machine the base could be faced with a slab mill, while the casting is secured in a machine vice; then, by inverting the casting and securing it by the tooled face to the machine table, the two sides can be dressed to exactly $2\frac{1}{2}$ in. apart by a pair of straddle mills. The clips holding the work down by the thin central portion the seating for the strips C can be faced to a previous setting of $\frac{7}{8}$ in. from the tooled-up base. While thus held the casting should be secured by the surfaces last tooled up, and a face and side cutter of $1\frac{1}{4}$ in. used to dress out the recess of B to the dimensions required.

Next we may clamp the strips C together, and with a pair of straddle mills at precisely one inch apart, face up the two sides of the strips together.

There are three methods of tooling the top and bottom surfaces, viz. first, they may be held in the machine vice, and faced singly by milling or shaping; second, by fixing the tooled surface to an angle plate; third, by clamping them to the table of the milling machine or shaping machine Since the surface is only 1 in. wide the best plan will be the first-named, tooling over by a vertical end mill, and then by turning the vice at right angles the ends can be faced to 3¼ in. apart whilst thus set, assuming the vice grips the work with one end projecting.

True up the pieces supplied to you to the shape and dimensions shown in the sketch, each of them being 6 in. long. Scrape the surfaces. Then, with the two pieces lying on a surface plate, the one on its edge ¾ in. wide, and the other on its edge 1¾ in. wide, fit the two sloping faces as you would the bevel of a slide rest (Fig. 226).

Answer. Set each casting evenly on a flat surface, the base of each lying as in sketch. A line can now be drawn across the ends at a full $\frac{1}{16}$ in. from the surface of the supporting table. By raising the finger of the surface gauge another line at precisely 1 in. above the first can be scribed; then, by means of a square, a vertical line may be scribed at one end of each casting, and the two pieces next turned to bring the vertical line into the horizontal plane. The correct setting can now be verified by accurately gauging the position of the lines at the ends now perpendicular, and 1 in. apart. This being satisfactory, the height of the line at the base can be obtained and transferred to each casting at the opposite end.

The angular side can be left until the other portions are tooled over; in fact, there is a decided advantage in tooling the surfaces marked at right angles in this case; by so doing the angle of 45° can be set and verified from either top or bottom surfaces, thus the tooling of the angular face can be regulated with absolute precision. The drawing shows this angle to terminate in a sharp edge, and a finishing cut can be best obtained with a knife tool, which happens to be the correct tool if the work cannot be milled. Milling is undoubtedly the best method of reducing the surfaces to dimensions, inasmuch as there is practically no subsequent dressing other than scraping the surfaces to make them pad evenly.

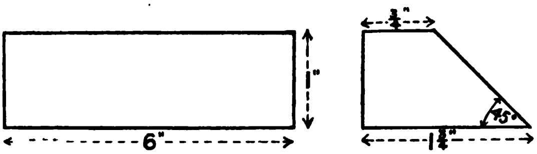


FIG. 226.—Truing up bevel surfaces.

Question. The general principles of iron forging (excepting welding) and the simple manipulation necessary for such have to be clearly demonstrated without a forge fire. What metal would you suggest as suitable for the purpose? State clearly and concisely the advantages, disadvantages, and any possible element of danger in your suggestion.

Answer. The principles of forging are the shaping of metal whilst in a very hot state, to a predetermined form.

The material may be forced into shape by hammering or by squeezing. Iron of a reliable quality may be drawn out from a thick to a thin bar, or shortened and thickened by upsetting the ends, or it may be twisted, pointed or flattened. It may be drawn into thin wire, so thin as to wind on a bobbin like cotton is wound. At first it has many impurities, these however, are eliminated in the furnace or beneath the power hammer or in the subsequent process of working it in the forge.

As a general principle the more iron is worked the tougher and stronger it becomes. In forging the iron must be hammered only while it is hot, otherwise it may lose its homogeneous quality.

Without a forge fire, copper rods may be hammered into shapes suitable in appearance to forged iron rods prepared for uniting.

The advantage of copper for the purpose is that it may easily be "upset," "drawn down," or pointed whilst cold. To effectively work it, however, it should retain its ductile and plastic qualities. This hammering cold destroys these qualities, and the metal becomes stiff, hard, and brittle; this is a disadvantage, and if persisted in would certainly cause fracture at or about the part hammered, hence the element of danger. All this may be eliminated by heating the cold hammered portions, to a red colour, and suddenly quenching off in cold water. This process restores to the copper all its original ductility, and hammering or bending may again be proceeded with until it again hardens, when the process should be again repeated; the actual change is called annealing.

FITTERS' AND TURNERS' WORK.

Question. The diameters of the steps of a cone pulley for a drilling machine are 6 in., $7\frac{1}{2}$ in., 9 in. and $10\frac{1}{2}$ in., and the countershaft cone pulley is similar. The countershaft runs at 320 revolutions per minute. Find the maximum and minimum number of revolutions of the cone pulley of the machine. Sketch an arrangement of pulleys on the countershaft so that the motion of the machine may be reversed. For what purpose is it required to reverse a drilling machine?

Answer. The speed cone on the countershaft will have its steps in the reverse order to those on the speed cone on the machine. Therefore the sums of the diameters of the steps in each case = $16\frac{1}{2}$ in. The speed of the countershaft is constant, viz. 320 revolutions per minute, therefore, when the belt is on the $10\frac{1}{2}$ in. step on the countershaft cone it will be on the 6 in. step on the machine cone pulley. This equals $\frac{10{\cdot}5 \times 320}{6} = 560$ which is the maximum speed, and when the belt is shifted to the 6 in. step on the countershaft cone, and the $10\frac{1}{2}$ in. step on the machine cone it will equal $\frac{6 \times 320}{10{\cdot}5} = 182{\cdot}856$, the minimum speed, *i.e.* roughly 183 revolutions (Fig. 227).

Drilling machines are reversed after the use of a screw tap just to withdraw it from the tapped hole, the spindle can then be moved until the tap is centrally over the next hole, and the tapping and reversing goes on as before. The arrangement of pulleys for reversing consists of an additional driving pulley on the main shaft, also an additional fast and loose pulley on the countershaft connected by a belt, the belt is crossed if the ordinary driving belt is an open one, or open if the ordinary driving belt is crossed (Fig. 227A).

Question. What is an alloy? Name one with which you are familiar and state definitely any advantage it may have over its constituents, and the *essential* properties of each metal.

Answer. An alloy is a mixture of two or more metals, *i.e.* copper and zinc melted together form brass. Copper is ductile and tough. It may be hammered and shaped either whilst hot or when cold. It is a bad metal to resist wear, and therefore is unsuitable for shaft bearings. After beating it must be softened or annealed to reduce the hardness. Zinc is a more brittle metal, and combines well with copper. The product, brass, is soft, medium, or hard, according to the percentages of the zinc and copper. The addition of a little tin makes a harder kind of brass suitable for bearings.

Brass is ductile, like copper, and may be beaten into different forms when cold with good results, if properly annealed. Brass, however, will not forge, and therefore must not be hammered whilst hot. This is owing to the low melting point of zinc.

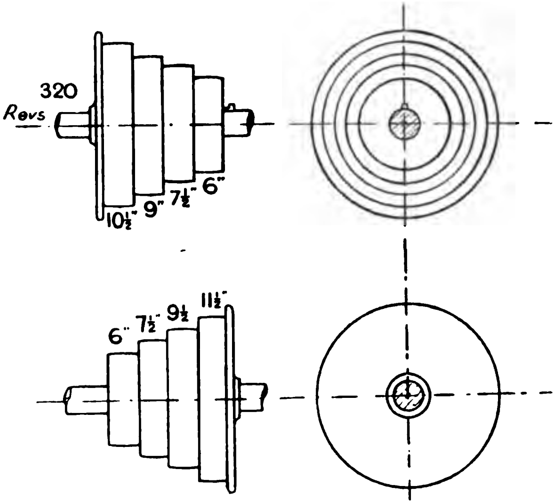


FIG. 227.—Speeding example.

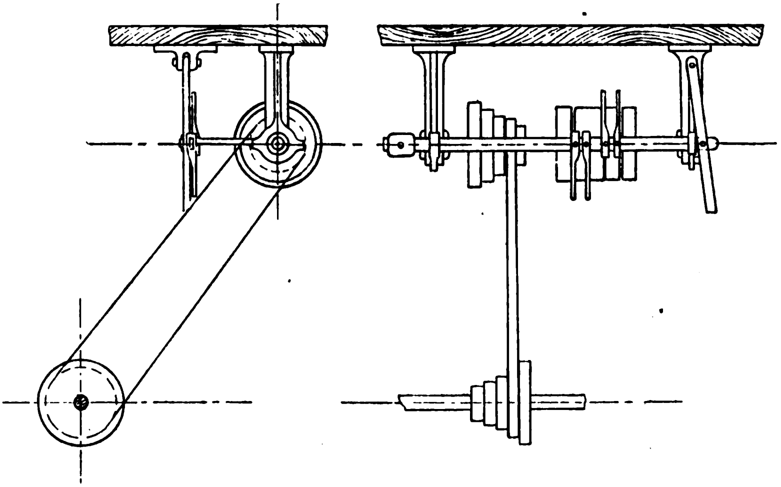


FIG. 227A.—Speed cone and pulley drive.

A much harder alloy is obtained by the mixing of 90 per cent. copper and 10 per cent. tin, with the addition of a little phosphorus. Copper or tin would be unsuitable substitutes, copper being soft, and more or less plastic.

The last-named alloy is known as phosphor bronze and has to be mixed most carefully. It is very strong and suitable for many purposes, such as bearings, pumps, hydraulic work, etc. It may be drawn out into wire or sheets and for many purposes cannot be superseded in mechanical and electrical engineering practice.

"Delta" metal—a bronze alloy—may be heated to 1000° F. (at which temperature it becomes plastic) and may thus be forged into bars, rods, or worked like iron (not including welding.)

Question. Write some notes of a lesson on the various methods employed for joining metals. Similar or dissimilar. Explain how, when, and why each method should be used as you would to a class of young students, dealing as far as you are able with the chemical, physical, and mechanical aspects of the different processes.

Answer. Explain the first essential—namely—cleanliness of surfaces to be joined, *i.e.* they must be free from grease or oil. Second, evenness of surfaces to be joined. Thin goods may be satisfactorily joined by soldering, such as tin to tin, brass to brass, copper to copper, or tin to brass, or tin to copper, etc.

The joining material is soft solder, an alloy of lead and tin and a little bismuth. Explain the advisability of having a solder which will melt at a low temperature so that the article to be soldered will not be damaged by heat. Give instances, such as the soldering of tin goods and small articles made of brass or copper.

Explain the desirability of having a suitable flux to assist the solder to flow along the joint or seam. Name some fluxes used, as "Fluxite" (a preparation), resin, or tallow. Explain the "soldering iron"—*not iron*, but a "copper bit," pointed and tinned. Explain the tinning process, also the care necessary to avoid overheating of the "iron," and about the uselessness of a burnt soldering iron. Explain hard soldering to be "brazing." State how the parts to be brazed are cleansed and put in position before brazing. Tubes may be pegged, small articles tied with wire, larger ones secured by cramps, etc. Explain the action of a flux to prevent oxide forming on the parts. How the flux prevents the part becoming damaged by heat. Explain "spelter" to mean very soft brass filings or soft brass ribbon, also that the flux (borax) may be mixed with the spelter first. Explain the advantage of a bath of molten spelter into which the articles may be immersed, as in the case of bicycle frames and similar parts, instead of simply pasting the spelter and borax around the joint. State that brazing is much more endurable than soldering.

Make it clear that brazing can only be satisfactory when the articles to be brazed have a higher melting point than the spelter, also that there is a partial fusion of the edges of the piece to be brazed; especially is this the case when brazing hard brass and copper goods. Explain the various methods of obtaining heat suitable for brazing, (1) smithy fire, (2) open fire, *i.e.* brazing hearth in any part of the workshop, to admit long pipes, etc., (3) blow-pipe. Show that the size of pipes for gas and air may be reduced as the articles to be brazed are of a reduced dimension.

Explain that the hearth may have charcoal, coke, or pumice stone for a bed, also that the gas and air jets may enter from a fixed or movable set of pipes.

Copper, iron, and steel tubes may have a plain single joint, or they may have a lap and straight joint at such intervals.

Explain riveting.

Riveting is the art of joining metal plates together, such as strong iron and steel plates, or copper work.

The holes through which the rivet passes may be punched cold, or hot, according to the thickness of the plates to be joined. The effect of punching is to alter the form of the fibre of the material around the hole, in which case the material is defective and may be the direct cause of fracture.

Explain the remedy for distorted plates.

Punched plates of iron and steel are partially restored by annealing.

Explain annealing to be softening by heating up the plates and allowing them to gradually cool.

Annealing copper is the reverse—heating up the plates and slacking or cooling them in water.

Explain drilling to be superior to punching. The holes are first evenly marked out, and then truly cut circular by means of a pointed drill; the drill being fed steadily through the metal causes no damage to the sides of the plate as it penetrates it.

Hints on Belts

When fixing a belt the fleshy side should be put next the pulley. Raw hide belts are stretched at the maker's; "tanned" beltings have to be stretched. This can be done by placing the belt over a shaft and securing a weight at the ends, additional weights being added as desired. In some cases when long belts are required they may be made to span two or more columns or other fixtures and then laced up, the tightening-up being effected by the use of a wooden roller and a pair of pulley blocks, and chain or sling. If an unstretched belt is erected in position, it will grow too slack for use during the day. Before an ordinary belt is taken up, the condition should be noted. A slipping belt may be remedied by a coating of dressing, especially is this the case if the pulley has a burnished face. Belts periodically dressed will hug the pulleys and thereby transmit more power.

Thin belts give better results than thick ones, and the more uniform the belts are at the joints the better they will drive. The ends are pared down for several inches, overlapped, and cemented together. They are then either riveted, laced, or sewn to give further support to the joint. If the paring is properly done, the belt will be no thicker at the joints than elsewhere. There are numerous forms of belt fasteners, made in malleable, cast iron, mild steel, and brass respectively. They all require the ends of the belt to be trimmed square, and generally half the fastener is secured in each end. There are two exceptions—one in which a lace is used, and the other when screws and nuts are used; in both cases the joint is overlapped. The quickest and perhaps easiest fastener to release is the screw and nut, or the brass double T. In the case of the latter, no difference is made whether the belt spans a large or a small pulley, the fastener may be bent and thus adapted to each curve. A belt always tends to climb to the largest diameter, therefore to ensure a straight drive the faces of pulleys are frequently rounded. To maintain the elasticity of a belt, when idle it should be released of its tension. To effect this, loose pulleys may be turned to a less diameter than the fast ones, while speed cone belts can usually be slipped off at week-ends, holidays, and always where the use of the machine is not constant.

Otherwise a belt after standing for a considerable time seems to get a permanent set, or loses its elasticity, and therefore slips. Great care must be exercised in taking up such belts to make them grip; if after a coating of dressing the belt shows little improvement in its transmitting power it may be concluded that the belt is fatigued and should be at once changed. In the larger machine shops duplicates of all belts are kept, so that there will be no loss of time in changing nor in effecting repairs.

Originally it was the practice to run close up to the driving capacity of a belt, especially in the heavy turning and planing departments—probably through the narrow speed cones and pulleys used, and the inefficiency of the tool steel to maintain its cutting edge on hard cast iron and hammered steel forgings. The instant a cutting tool loses its edge the pull on the belt is considerably increased and soon more than doubled. Therefore it must be obvious that tightening up of the belts is not a cure, because by so doing the friction on both machine and overhead bearings is proportionately increased, and thereby tending to stop the drive. In this way new belts may be made useless in a few days if too weak for their task. Since the adoption of the high-speed steel there has been a great improvement in the above particular, the width of speed pulleys and speed cones have been more than doubled, leaving a greater reserve of driving power and consequently longer life given to the belts.

DEFINITIONS

STRAIGHT-EDGE (Fig. 2).—A straight-edge is a rectangular strip of mild steel. One edge is bevelled, but both edges are truly scraped and are parallel with each other.

SURFACE PLATE.—A surface plate is a cast-iron true plate usually made to stand on three feet to keep it steady, and tied with ribs on the under side to keep it from warping. Great care is exercised in tooling up the surface, and, to allow the metal to take a permanent set, the casting is laid aside some weeks before the final tooling is proceeded with. A fine scraping cut is then taken and the plate is tested on a true plate and scraped by hand until the points of contact are very numerous and evenly distributed over the entire surface.

DEPTH GAUGE.—A depth gauge is made in two parts. The first is usually a rectangular block with a slot or hole passing through it at right angles, and the other a strip or rod which may protrude through the block any desired distance and which is secured by a setting screw. The best form of depth gauge is that one with divisions of an inch marked clearly on the strip. The depth gauge made thus will indicate the precise depth of any recess being tooled, and is therefore in frequent use at milling, shaping, or planing machines. This instrument is very useful in setting down shoulders from a given surface such as the shoulders on the sheaf of an engine eccentric, also when recessing the eccentric straps in the lathe.

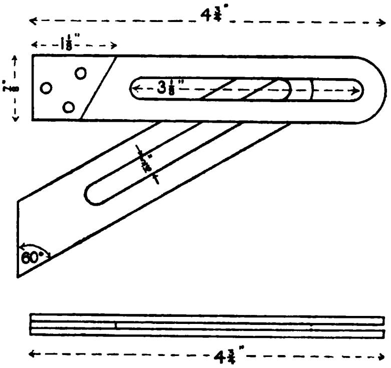


FIG. 228.—Bevel squares.

BEVEL SQUARE (Fig. 228).—A bevel square is provided with a swivelling blade, which may be set and secured to any desired angle. By its use angular work may be correctly set out and gauged subsequent to tooling.

The tooling of Vee slides and setting-up strips and dovetail work are among the parts requiring a bevel square.

Protractor.—A protractor is divided into degrees, and is sometimes combined with a bevel square, in which case it must be most useful, as the possibility of error in transferring the inclination or angle is eliminated. The dial is graduated in degrees round the whole circle.

Prick Punch.—This is a $\frac{5}{16}$ in. or $\frac{3}{8}$ in. rod of tool steel about 3 in. long. One end is hardened and tempered and is ground to a very sharp point. It is used to locate positions of lines, centres, or circles.

Centre Punch.—This is a larger kind of punch used to enlarge centred holes, and is especially in request at the marking-off table, the lathe, and at a general drilling machine.

Drawing Chisel.—This is used to draw a centre for a hole which has commenced to wander. It is effective *before* the full diameter of the drill has entered the metal. *After* this the drill will not be coerced.

Tapping Size.—This diameter is fractionally larger than the root diameter of the screw to be used, and proportionally increases as the diameter and pitch of the screw increase. This applies to Vee threaded screws.

Wrought Iron and Mild Steel can be drilled and tapped, leaving the hole with a screw thread practically to a full size and finish.

Cast Iron.—Tapping size for this metal must be slightly in excess of the above, because the metal being granular in construction will not admit of any squeezing to round off the tops of the threads.

Castings are made of iron, steel, brass, bronze, aluminium, and are produced by pouring molten metal into moulds.

Forgings always means metal wrought by heat and hammering or bending or squeezing into shape. There are several ways of obtaining the result. Example :—A screw bolt may be built up of two parts and united by welding, or the screw bolt may be "drawn out" from a solid bar at the anvil or power hammer according to its dimensions. Finally, a screw bolt may be formed at one heat by placing a heated bar between an upper and a lower die.

Stamping or Drop-forging.—This is the technical term given to the last-named process. Both are worked under the power hammer, *i.e.* the impression of the dies being stamped on the article between them, and hence the term "stamping," while "drop-forging" signifies that the article produced has been made by means of a falling weight or hammer.

Planishing is the smoothening and levelling of plates, bars, or sheets of metal between two surfaces, such as between the anvil face and the hammer face of a power hammer.

Pallets signifies the face of the hammer and anvil beneath it.

Annealing.—Articles may be softened or annealed by heating and slowly cooling them. Generally speaking, the slower the heating and cooling, the more thorough the annealing.

Hammered Forgings are finally slowly heated and laid on the floor to cool. This renders them soft throughout.

Hard Cast Iron may be annealed by heating the castings in an oven and uniformly cooling them, *i.e.* by letting the oven cool down gradually.

Copper becoming hard by working may be annealed if made red hot and cooled in water.

Malleable Iron, or iron that has been thoroughly annealed, is wrought iron, the best brands being Swedish, Lowmoor, Crown, Staffordshire, Yorkshire, Butterley, etc.

Malleable Iron Castings will, when properly annealed, bend or submit to twisting. The castings originally made of white pig iron are quite hard and brittle, but after dressing they are placed in an oven with powdered hæmatite, and the oven is then sealed and made red hot; the hæmatite (peroxide of iron), the oxygen from which combines with the carbon which is thus partially removed from the iron, leaving the product malleable. The time during which the castings are submitted to the above treatment varies with the size of the articles, and may be from one to two weeks or more.

PICKLING CASTINGS, &C.—This term applies to the placing of castings or forgings in a bath of dilute sulphuric acid. By this means the scale is burnt off, leaving the work clean and less likely to resist the action of the cutting tools.

LUBRICANTS.—When tooling wrought iron, mild steel, tool steel, and copper, the lubricant is generally soapy water, lard, or sperm oil, according to the size, speed, and continuity of the cutting process. Heavy work having deep cuts taken is lubricated with soapy water. Fine milling, turret lathe, and screwing machine work is lubricated with oil, or an oily mixture.

PACKING.—Packing signifies supporting work by means of parallel strips or blocks of metal which are machined reliably true. These supports are mostly afforded to pieces of mechanism which have been fully or partly tooled beneath the surface exposed for tooling. In some cases special packings are used. In the heavy classes of work the supports are of wood, and frequently the blocks have to be made to the same contour as the work. If this is not done, the parts are wedged until they are satisfactorily solid. As a general principle the securing bolts should be placed close to the points of support. See levelling work to be planed.

ROUGHING-OUT.—Pieces of work, whenever practicable, should be roughed out to shape all over before any part is finally finished. Work between the centres of a lathe may necessarily revolve for a considerable time on one centre, and when reversed may revolve for a short period or for a considerable time. It will be found that the pressure exerted enlarges the centre hole, and the irregular shape of, or want of homogeneity in, the metal may wear the centre unduly. An example of this irregular wear occurs in the turning of long shafts. The shafts are turned almost their whole length and then reversed. It will be found that the turned portions are not now axially true, and before any work can be done the centre will have to be drawn and the shafts straightened. In a similar manner heavy machine spindles which are in the first place more or less irregular forgings would be at once spoilt were any portions to be reduced to finished dimensions before other portions had been thoroughly reduced, leaving, say, but a small margin for finishing at every part. Castings in iron are all the better for a thorough roughing and then a rest, even if they are badly wanted. This is owing to the parts assuming a different shape when once tooled over. An example of this occurs in the making of a surface plate; this is roughed out and laid to rest for a few weeks, on resetting on the machine table the tooled surface will be found more or less irregular; so that a final light cut is necessary before hand-scraping is resorted to.

EXAMPLES FOR STUDENTS IN MANUAL TRAINING METAL WORK

An axle is shown as finished in Fig. 229.

Since it is not general to set down the ends in the smithy, the forging should be laid by the part B on Vee blocks, then with the scribing block finger set for the mean of A, E, lines can be drawn across the ends, and by giving the work $\frac{1}{4}$ and $\frac{1}{2}$ turns respectively approximate centres for A, E will be determined, and a centre dot on each end made with a punch. See also Figs. 230, 231, the marking of a parallel shaft, and the use of odd leg calipers for finding centre at ends of a short rod in the vice, or by the aid of a centre square.

After the axle is centred, straightened, and faced, it is tooled roughly on the largest diameters, then the lengths at B, C, D set down, leaving A and E until a final cut has been taken and the various shoulders finished to length. The carrier may be placed on A whilst E is reduced, and on D whilst A is turned to $\frac{1}{2}$ in.; in this way the important part of the axle B will not be bruised.

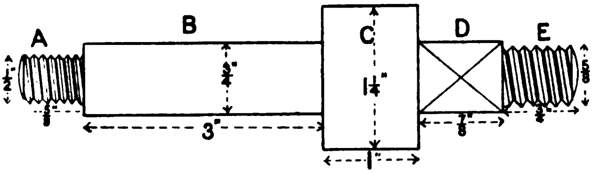


FIG. 229.—Forged axle turned and chased.

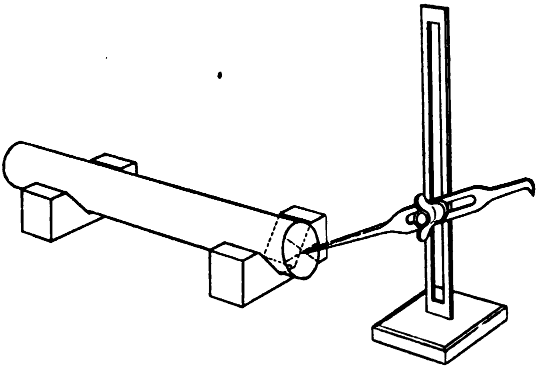
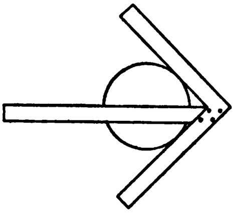


FIG. 230.—Centring short shaft on Vee blocks.

Now the screw threads may be struck and hand chased or cut by the aid of a guide screw and change wheels. See Examples A, B, C, and D, Fig. 140, showing uses of change wheels.

Referring to the straightening of the axle or shaft, a small straightening press is shown in Fig. 232. The heads AA will move along the bed B, the work being held between the centre points C. When the highest point has been found the work is supported at D, and the pressure screw E is used, actuated by the handwheel F. The work is rotated, chalked, and straightened until satisfactory. The ordinary compound gear or back gearing to a lathe fast headstock, may be engaged or disengaged by a horizontal sliding movement, or by the use of an eccentric shaft, as shown in Fig. 233 in detail. The gears are connected by a long sleeve which just fills in between the faces of the bearings at GG. For this purpose the bush bearing D is loose, and is not fitted to its place until the shaft and gearing are assembled in the headstock, when it is driven on to its key at C. Then, by movement of the handle E, the shaft is rotated on its bearings AD, but since the part B or eccentric the gears riding thereon will move towards the spindle gears, or away from them just as the direction of the handle is moved. Passing through the bearing where the solid part of the shaft A rides, and through A vertically) is a parallel hole for a retaining pin, shown on A at F.

The gears are all assembled and the pin keeps them in place. When not required the shaft is moved and the pin again inserted, so that the gearing cannot now be connected. To effect this the drill is passed through the shaft at two points when this part of the mechanism is under construction. An example is given in Fig. 234, showing the testing of a lathe face plate for accuracy.



Centre square.

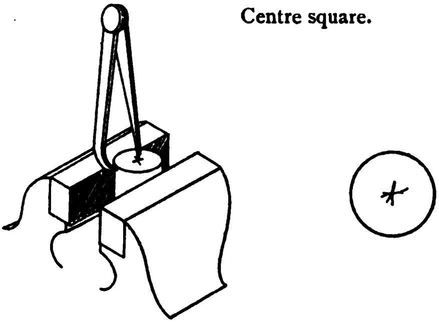


FIG. 231.—Centring short shaft in vice.

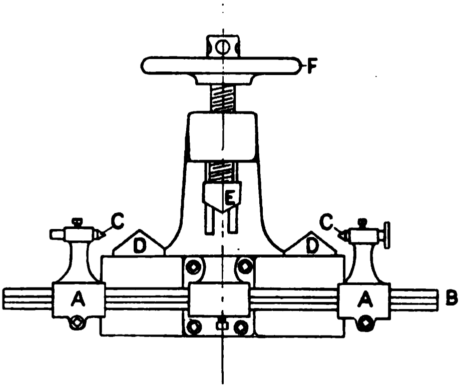


FIG. 232.—Bench straightening press.

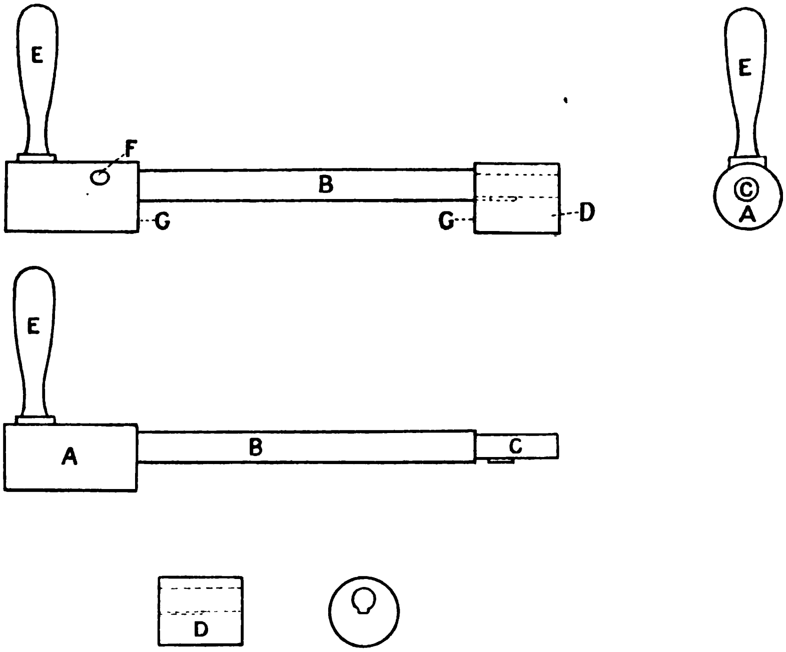


FIG. 233.—Eccentric shaft for back gear of lathes.

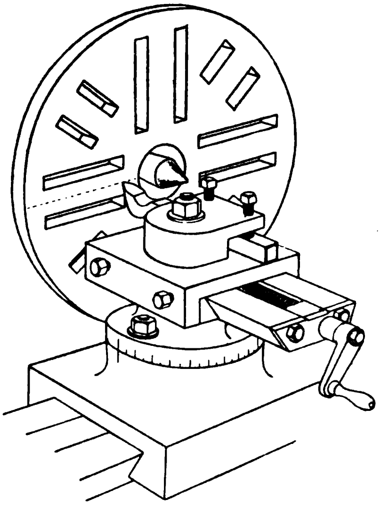


FIG. 234.—Testing truth of lathe face plate.

The tool is fixed on the centre line, and a faint line traced across the surface of the plate. Then, assuming that the plate is quite true to a straight-edge held on the face, the plate should be perfectly at right angles when a square is held on the face and the stock on the lathe bed. If this is quite correct the lathe spindle is parallel with the bed, and the transverse slide at right angles to it. Therefore the lathe should surface, bore, or turn satisfactorily in every respect.

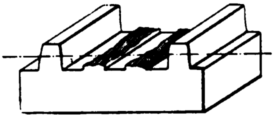


FIG. 235.—Rack with broken teeth.

A final example is given in Fig. 235 showing a piece of gear rack with two fractured teeth. To effect a lasting repair a piece of mild steel would be dovetailed in and the new teeth marked out, and shaped or milled to gauge. Fig. 236 is a typical example of the drawing required.

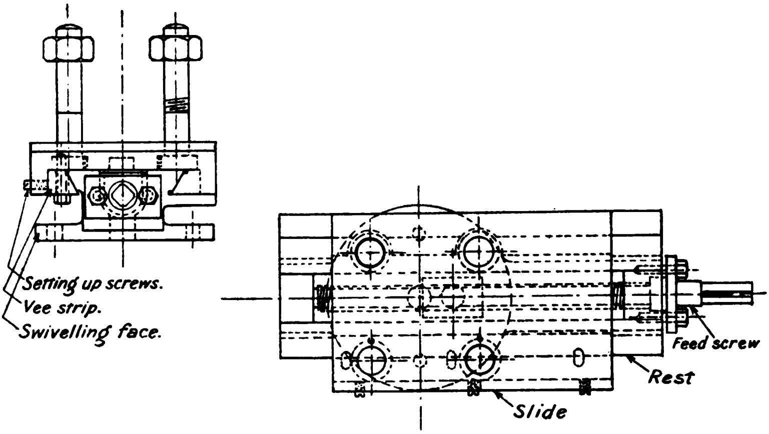


FIG. 236.—Lathe slide and rest to be drawn.

TEMPERING SPRINGS

To temper springs successfully very much depends upon the temperature of the oil in which the springs are placed after hardening, and of the kind of steel which is used, and the purpose to which the springs are put.

Very thin strip steel which must eventually be made quite " springy " will be placed in an oil bath, say, of 500° F. Small articles of this description may be conveniently held in the oil bath by placing them in a wire basket and kept under the surface until the oil has reached the proper temperature, which should be gauged by a thermometer. The most convenient form of heating is by gas. Thicker articles which have to be less springy are not heated to so high a temperature in the oil. Some low-grade steel will hold its elasticity when the temper has been but little drawn. On the other hand, steel of a higher grade will need special care in hardening and subsequent tempering if good results are to follow.

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